SECTION 6. CHESAPEAKE BAY TMDL DEVELOPMENT

This section discusses the critical elements of the Chesapeake Bay TMDL, many of which benefitted from joint collaboration and decision making by EPA and its partners. The following subsections discuss the specific approaches adopted to address specific technical aspects of the Chesapeake Bay TMDL:

- 6.1-Establishing Model Parameters
- 6.2-Interpreting Model Results
- 6.3-Establishing Allocation Rules
- 6.4-Assessing Attainment of Proposed Amended Chesapeake Bay WQS
- 6.5-Assessing Attainment of Current Chesapeake Bay WQS
- 6.6-Setting Draft Basin-jurisdiction Allocations

The Chesapeake Bay Program partners initiated discussions related to the technical aspects of the Chesapeake Bay TMDL starting at the September 2005 Reevaluation Workshop sponsored by what would become the partnership's Water Quality Steering Committee (Chesapeake Bay Reevaluation Steering Committee 2005). Over the next 5 years, EPA and its partners, in particular members of the Water Quality Steering Committee (2005–2008) and then the Water Quality Goal Implementation Team (WQGIT) (2009–present) systematically evaluated and agreed on approaches to address multiple technical aspects related to developing the Bay TMDL.

EPA, together with its seven watershed jurisdictional partners, developed approaches and methodologies to address a number of factors and then applied those approaches and methodologies in developing the Bay TMDL. A multitude of policy, programmatic, technical, and model setup/application issues were addressed through this collaborative process.

6.1 Establishing Model Parameters

The first step in the process was to establish the key parameters for the model. Those key parameters are (1) the hydrologic period, or the period that is representative of typical conditions for the waterbody; (2) the critical conditions, or the selection of a set of years that represent the range of conditions affecting attainment of the Bay WQS; (3) the WQS protective of all the Bay habitats and the aquatic life inhabiting those habitats; and (4) the seasonal variation in water quality conditions and the factors (temperature, precipitation, wind, and such) that directly affect those conditions.

6.1.1 Hydrologic Period

The hydrologic period for modeling purposes is the period that represents the long-term hydrologic conditions for the waterbody. This is important so that the Bay models can simulate local long-term conditions for each area of the Bay watershed and the Bay's tidal waters so that no one area is modeled with a particularly high or low loading, an unrepresentative mix of point and nonpoint sources or extremely high or low river flow. The selection of a representative hydrologic averaging period ensures that the balance between high and low river flows, the resultant point and nonpoint source loadings areas across the Bay watershed and Bay tidal waters are appropriate. That provides the temporal boundaries on the model scenario runs from which the critical period is determined.

To identify the appropriate hydrologic period, EPA analyzed decades of historical streamflow data. It is important to identify representative hydrology to be able to compare various management scenarios through the Bay models. In the course of evaluating options for the TMDL, EPA and the partnership ran numerous modeling scenarios through the Bay Watershed and the Bay Water Quality Sediment Transport models with varying levels of management actions (such as land use, BMPs, wastewater treatment technologies, and so on) held constant against an actual record of rainfall and meteorology to examine how those management actions perform over a realistic distribution of simulated meteorological conditions. It was important that this record of precipitation and meteorology, or hydrologic period be representative of local long-term conditions for each area of the watershed so that no one area is modeled with a particularly high or low loading or an unrepresentative mix of point and nonpoint sources.

Because of the long history of monitoring throughout the Chesapeake Bay watershed, the CBP partners were in the position of selecting a period for model application representative of typical hydrologic conditions of the 21 contiguous model simulation years—1985 to 2005. Two extreme conditions occurred during the 21-year model simulation period for the Chesapeake Bay models: Tropical Storm Juan in November 1985, and the Susquehanna Big Melt of January 1996. In the Chesapeake Bay region, Tropical Storm Juan was a 100-year storm primarily affecting the Potomac and James River basins. No significant effect on SAV or DO conditions was reported in the aftermath of Tropical Storm Juan. In the case of the Susquehanna Big Melt in January 1996, a warm front brought rain to the winter snow pack in the Susquehanna River basin and caused an ice dam to form in the lower reaches of the river. No significant effects on SAV or DO were reported from this 1996 extreme event, likely because of the time of year when it occurred (late winter).

From the 21-year period, EPA selected a contiguous 10-year hydrologic period because a 10-year period provides enough contrast in different hydrologic regimes to better examine and understand water quality response to management actions over a wide range of wet and dry years. Further, a 10-year period is long enough to be representative of the long term flow (Appendix F). Finally, a 10-year period is not overly burdensome on computational resources, particularly for the Bay WQSTM, which required high levels of parallel processing for each management scenario. The annualized Bay TMDL allocations are expressed as an average annual load over the 10-year hydrologic period.

EPA then determined which 10-year period to use by examining the statistics of long-term flow relative to each 10-year period at nine USGS gauging stations that discharge to the Bay (Appendix F). All the contiguous 10-year hydrologic periods from 1985 to 2005 appeared to be suitable because clear quantifiable assessments showed that all the contiguous 10-year periods have relatively similar distributions of river flow.

EPA selected the 10-year hydrologic assessment period from 1991 to 2000 from the 21-year flow record for the following reasons:

- It is one of the 10-year periods that is closest to an integrated metric of long-term flow.
- Each basin has statistics for this period that were particularly representative of the long-term flow.
- It overlaps several years with the previous 2003 tributary strategy allocation assessment period (1985–1994), which facilitated comparisons between the two assessments.
- It incorporates more recent years than the previous 2003 tributary strategy allocation assessment period (1985–1994).
- It overlaps with the Bay water quality model calibration period (1993-2000), which is important for the accuracy of the model predictions.
- It encompasses the 3 year critical period (1993–1995) for the Chesapeake Bay TMDL as explained in Section 6.1.2 below.

More detail about the hydrologic period is provided in Appendix F.

6.1.2 Critical Conditions

TMDLs are to identify the loadings necessary to achieve applicable WQS. The allowable loading is often dependent on key environmental factors, most notably wind, rainfall, streamflow, temperature, and sunlight. Because these environmental factors can be highly variable, EPA regulations require that in establishing the TMDL, the critical conditions (mostly environmental conditions as listed above) be identified and employed as the design conditions of the TMDL (40 CFR 130.7(c)(1)).

When TMDLs are developed using supporting watershed models, such as the Chesapeake Bay TMDL, selecting a *critical period* for model simulation is essential for capturing important ranges of loading/waterbody conditions and providing the necessary information for calculating appropriate TMDL allocations that will meet WQS. Because the WQS applicable to this TMDL are assessed over 3-year periods, the critical period is defined as the 3-year period within the 1991–2000 hydrologic period that meets the above description (USEPA 2003a).

Critical Conditions for DO

In the Chesapeake Bay, as flow and nutrient loads increase, DO and water clarity levels decrease (Officer 1984). Therefore, the critical period for evaluation of the DO and water clarity WQS are based on identifying high-flow periods. Those periods were identified using statistical analysis of flow data as described below and in detail in Appendix G.

For the Bay TMDL, EPA conducted an extensive analysis of streamflow of the major tributaries of the Chesapeake Bay as the primary parameter representing critical conditions. In this analysis, it was observed that high streamflow most strongly correlated with the worst DO conditions in the Bay. This is logical because most of the nutrient loading contributing to low DO comes from nonpoint sources, whose source loads are driven by rainfall and correlate well to rainfall and higher streamflows.

Because future rainfall conditions cannot be predicted, EPA analyzed rainfall from past decades to derive a critical rainfall/streamflow condition that would be used to develop the allowable loadings in the TMDL. The initial analysis concluded that the years 1996–1998 represented the highest streamflow period for the Chesapeake Bay drainage during the 1991–2000 hydrology period. However, it was later discovered that this 3-year period represented an extreme high-flow condition that was inappropriate for the development of the TMDL—the high-flow period would generally occur once every 20 years (Appendix G). For that reason, EPA selected the second highest flow period of 1993–1995 as the critical period. The 1993–1995 critical period experienced streamflows that historically occurred about once every 10 years, which is much more typical of the return frequency for hydrological conditions employed in developing TMDLs. Thus, while the modeling for the Bay TMDL consists of the entire hydrologic period of 1991–2000, EPA used the water quality conditions during the 1993–1995 critical period to determine attainment with the Bay jurisdictions' DO WQS.

Critical Conditions for Chlorophyll a

To assess attainment of the numeric chlorophyll *a* criteria that apply to Virginia's tidal James River and the District of Columbia's tidal Potomac and Anacostia rivers, EPA conducted a similar analysis of streamflow. The analysis showed no strong correlation between streamflow and chlorophyll *a* conditions. As a result, EPA assessed numeric chlorophyll *a* attainment using all eight of the 3-year criteria assessment periods (e.g., 1991–1993, 1992–1994) that occur within the hydrologic period of 1991–2000. Detailed technical documentation of this assessment is provided in Appendix F.

Critical Conditions for Water Clarity and SAV

In the Chesapeake Bay, the water clarity and SAV WQS are applied Bay-wide. Further, sediment has similar loading attributes as does nutrients (higher loads under higher streamflow). Therefore, the critical period for evaluating attainment of the SAV and water clarity WQS is based on identifying high-flow periods, just as it is for DO.

As discussed above, because the WQS applicable to the Bay TMDL are assessed over 3-year periods, the critical period is defined as the 3-year period within the 1991–2000 hydrologic period that represents the range of critical conditions affecting attainment of the Bay WQS (USEPA 2003a). Because the critical period for both DO and water clarity/SAV is based on identifying high-flow periods, EPA used the same analysis as it did for nutrients. As a result of the analysis, EPA determined that the same critical period used for DO was appropriate for water clarity/SAV. As with nutrients, detailed technical documentation is provided in Appendix F.

6.1.3 Water Quality Standards

A TMDL must allocate allowable loads to the contributing point and nonpoint sources so that all applicable WQS are attained for each of these segments (CWA section 303(d)(1)(C)). The applicable Bay WQS and the proposed amended WQS are summarized here and discussed in greater detail in Section 3.

Proposed Amendments to the Jurisdictions' Bay Water Quality Standards

During the water quality modeling and data analysis process to establish the Chesapeake Bay TMDL, it became apparent that a small number of the 92 tidal segments would not attain the applicable WQS even when nitrogen and phosphorus allocations consistent with the longstanding jurisdictions' tributary strategies were achieved.

Using modeling and other informational lines of evidence, EPA concluded that the water quality in these few segments did not respond to the nutrient or sediment load reductions as expected because of the following:

- The influence of pycnoclines, which limit re-aeration of the bottom waters prevent attainment of the open-water DO criteria.
- Limitations in the ability of the Bay Water Quality Model to adequately simulate water quality responses to nutrient reduction in certain, small, narrow segments.
- The adoption of SAV restoration acreage criteria that were derived using a methodology that was inconsistent with that used in the vast majority of other Chesapeake Bay segments.

Subsequent modeling evaluations of alternative allocation scenarios concluded that for all 92 segments to meet the applicable Maryland, Virginia, Delaware, and District of Columbia WQS, reductions from both point and nonpoint sources throughout the Bay watershed would need to be established at the E3 (Everything, Everywhere, Everyone) annual level of 141 million pounds of nitrogen and 8.5 million pounds of phosphorus (Appendix J). The E3 scenario represents a *best case* possible situation, where all possible BMPs and available control technologies are applied to land, given human and animal populations and wastewater treatment facilities are represented at highest technologically achievable levels of treatment regardless of costs. The Bay-wide loading target that otherwise would be distributed among all seven jurisdictions would be 187 million pounds of nitrogen and 12.5 million pounds of phosphorus. Thus, to attain WQS in these few tidal segments would require an additional Bay-wide reduction in nitrogen and phosphorus of 25 percent and 33 percent, respectively.

To address these needed water quality standards refinements, Maryland, Virginia, and the District of Columbia are each proposing amendments to their respective Chesapeake Bay WQS regulations directly relevant to the Bay TMDL. Delaware has already adopted the EPA-published 2010 Bay criteria addendum into its WQS regulations by reference.

Current Chesapeake Bay Water Quality Standards

As discussed above, the allocations required to meet currently applicable Chesapeake Bay WQS, as required by the CWA and federal regulations, are not reflective of EPAs latest scientific assessment of appropriate criteria for the Bay, As a result, Maryland, Virginia, and the District of Columbia are in the process of amending their respective WQS regulations.

In the time between the issuance of this draft TMDL and the date of completing the final Bay TMDL, EPA will closely monitor the progress of the jurisdictions in their WQS adoptions. As revisions occur over that time frame, EPA will conduct additional modeling runs necessary to establish the allocations that would result in full attainment of the applicable WQS in place as of December 31, 2010. It is possible, however, that the amendments will not be effective before establishing the final Bay TMDL on December 31, 2010. Therefore, EPA is also providing for public comment a Bay TMDL based on the jurisdictions' current Bay WQS, as required by the CWA and federal regulations.

6.1.4 Seasonal Variation

A TMDL analysis must consider the seasonal variations within the watershed (CWA 303(d)(1)(C); 40 CFR 130.7). The Chesapeake Bay TMDL inherently considers all seasons through the use of a continuous 10-year simulation period that captures seasonal precipitation on a year-to-year basis throughout the entire watershed. Furthermore, the critical periods selected for this TMDL, being a minimum of 3 consecutive years provide further assurance that the seasonality of the bay loading and other dynamics are properly addressed in this TMDL. In this way, the TMDL simulations ensure attainment of WQS during all seasons.

Jurisdictions' Bay Water Quality Standards

In the case of the Chesapeake Bay TMDL, the Chesapeake Bay WQS adopted by the four tidal Bay jurisdictions are biologically based and designed to be protective of Chesapeake living resources, including full consideration of their unique seasonal-based conditions (see Section 3) (USEPA 2003a, 2003c). To assess the degree of WQS achievement using the Bay Water Quality Model, an overlay of the time and space dimensions are simulated to develop an assessment that is protective of living resources with consideration of all critical periods within the applicable seasonal period (USEPA 2007a).

The same approach of considering the time and space of the critical conditions is applied in the assessment of the WQS achievement with observed monitoring data. Ultimately, the time and space of water quality exceedances are assessed against a reference curve derived from healthy living resource communities to determine the degree of WQS achievement (USEPA 2007a).

Model Simulation Supporting Seasonal Variation

The suite of Chesapeake Bay Program models being used to establish the Chesapeake Bay TMDL—Bay Airshed, Bay Watershed, Bay Water Quality, Bay Sediment Transport, Bay filter feeders—all simulate the 10-year period and account for all storm events, high flows/low flows, and resultant nutrient and sediment loads across all four seasons. The full suite of Chesapeake Bay models operate on at least an hourly time-step and often at finer time-steps for the Bay Airshed Model and the Bay Water Quality Model (see Section 5). Therefore, through proper operation of the suite of Bay models, the Chesapeake Bay TMDL considers all seasons and within season variations through the use of a continuous 10-year simulation period (see Section 6.1.1).

Seasonal Variations Known and Addressed through Annual Load Reductions

A key aspect of Chesapeake Bay nutrient dynamics is that annual loads are the most important determinant of Chesapeake Bay water quality response (USEPA 2004c). Chesapeake Bay physical and biological processes can be viewed as *integrating* variations in nutrient and sediment loads over time. The integration of nitrogen, phosphorus, and sediment loads over time reduces load fluctuations in the Chesapeake Bay. Bay water quality responds to overall loads on a seasonal to annual scale, while showing little response to daily or monthly variations within an annual load.

Numerous Chesapeake studies show that annually based wastewater treatment nutrient reductions are sufficient to protect Chesapeake Bay water quality (Linker 2003, 2005). The seasonal aspects of the jurisdictions' Chesapeake Bay WQS are due to the presence of the living resources being protected, but annual nutrient and sediment load reductions are most important to achieve and maintain the seasonal water quality criteria, some of which span multiple seasons—open-water, shallow-water bay grass, migratory spawning and nursery (USEPA 2003a, 2003c).

6.2 Interpreting Model Results

The WQSTM is used to predict water quality conditions for the various loading scenarios explored. It is necessary to compare these model results with the operative WQS to determine compliance with the standards. This section describes the process by which model results are compared to WQS to determine attainment.

6.2.1 Criteria Assessment Procedures

Determining Attainment of DO and Chlorophyll a Criteria

In general, to determine management scenarios that achieved WQS, EPA ran model scenarios representing different nutrient and sediment loading conditions using the Bay Watershed Model. EPA then took the resultant model scenario output and provided input into the Bay Water Quality Model to evaluate the response of critical water quality parameters: specifically DO, water clarity, underwater Bay grasses and chlorophyll *a*.

To determine whether the different loading scenarios met the Bay DO and chlorophyll *a* WQS, EPA compared the Bay Water Quality Model's simulated tidal water quality response for each variable to the corresponding observed monitoring values collected during the same 1991-2000 hydrological period. In other words, the Bay Water Quality Model was used primarily to estimate the change in water quality that would result from various loading scenarios with the model-simulated change in water quality then is applied to the actual observed calibration monitoring data. In its simplest terms, the following steps were taken to apply the modeling results to predict Bay DO and chlorophyll *a* WQS attainment:

1. Using the 1991 to 2000 hydrologic period, calibrate the Bay Water Quality Model to Bay water quality monitoring data.
2. Run a model simulation for a given *loading scenario* (usually a management scenario resulting in lower loads relative to the calibration scenario) through the Bay Watershed Model and Bay Water Quality Model.
3. Determine the model simulated change in water quality from the calibration scenario to the given loading scenario.
4. Apply the change in water quality as predicted by the Bay Water Quality Model to the actual historical water quality monitoring data used for calibration and evaluate attainment based on this *scenario modified* data set.
5. If WQS are met, then allocations are used for TMDL. If WQS are not met, reduce and readjust loads to meet WQS.

For a full discussion of this procedure, see Appendix I and the original report titled *A Comparison of Chesapeake Bay Estuary Model Calibration With 1985–1994 Observed Data and Method of Application to Water Quality Criteria* (Linker et al. 2002).

Determining Attainment of Water Clarity and SAV Water Quality Criteria

The Chesapeake Bay SAV restoration acreage and resultant WQS are based on achieving SAV acreage goals that were based on the highest SAV acreage ever observed over a 40-year to more than 70-year historical record depending on the records available for each basin (USEPA 2003a; 2003c). Bay-wide, the SAV restoration goal is 185,000 acres.

The linked SAV and water clarity WQS are unique in some respects. Rather than covering the entire Bay as the DO WQS does, the SAV-water clarity WQS applies in only a narrow ribbon of shallow water habitat along the shoreline in depths of 2 meters or less. That presents certain challenges for the Chesapeake Bay model simulation and monitoring systems, both of which have long been more oriented toward the open waters of the Chesapeake Bay and its tidal tributaries. Scientific understanding of the transport, dynamics, and fate of sediment in the shallow waters of the Chesapeake Bay and understanding and simulating all the factors influencing SAV growth continues to develop. Appendix H provides more details of the Chesapeake Bay WQSTM-based combined SAV-water clarity attainment assessment procedures and developing the sediment allocations.

The combined SAV/water clarity WQS can be achieved in one of three ways (see Section 3.4.3). First, as SAV acreage is the primary WQS, the WQS can be achieved by the number of SAV acres measured by way of aerial surveys—the method that is primarily used in CWA section 303(d) assessments. Second, the WQS can be achieved by the number of water clarity acres (divided by a factor of 2.5) added to the measured acres of SAV. Third, water clarity criteria attainment can be measured on the basis of the cumulative frequency distribution (CFD) assessment methodology using shallow-water monitoring data.

Although SAV responds to both nutrient and sediment loads, DO and chlorophyll *a* primarily respond only to nutrient loads. Because of that hierarchy of WQS response, the strategy developed to achieve WQS was to first set the nutrient allocation for achieving all the DO and chlorophyll *a* WQS in all 92 segments, and then set additional sediment reductions where needed to achieve the SAV/water clarity WQS. That strategy is augmented by management actions in the watershed to reduce nutrient and sediment loads.

Just as the SAV resource is responsive to nutrient and sediment loads, many management actions in the watershed that reduce nutrients also reduce sediment loads. Examples include conservation tillage, farm plans, riparian buffers, and other key practices. The estimated ancillary sediment reductions from nutrient reductions needed at the level of the proposed amended WQS-based allocation scenario are estimated to be about 40 percent less than 1985 sediment loads and 25 percent less than current (2009) load estimates. The sediment reductions associated with the nutrient controls necessary to achieve the basin-jurisdiction target loads provided on July 1, 2010, is provided in Table 6-1.

Table 6-1. Tributary strategy and proposed amended Bay WQS-based allocation scenarios TSS loads (millions of pounds) by jurisdiction

Jurisdiction	Tributary strategy	Allocation scenario—proposed WQS
Maryland	1,195	1, 118
Pennsylvania	2,004	1,891
Virginia	2,644	2,434
District of Columbia	10	10
New York	310	291
West Virginia	248	240
Delaware	55	55
Total	6,467	6,040

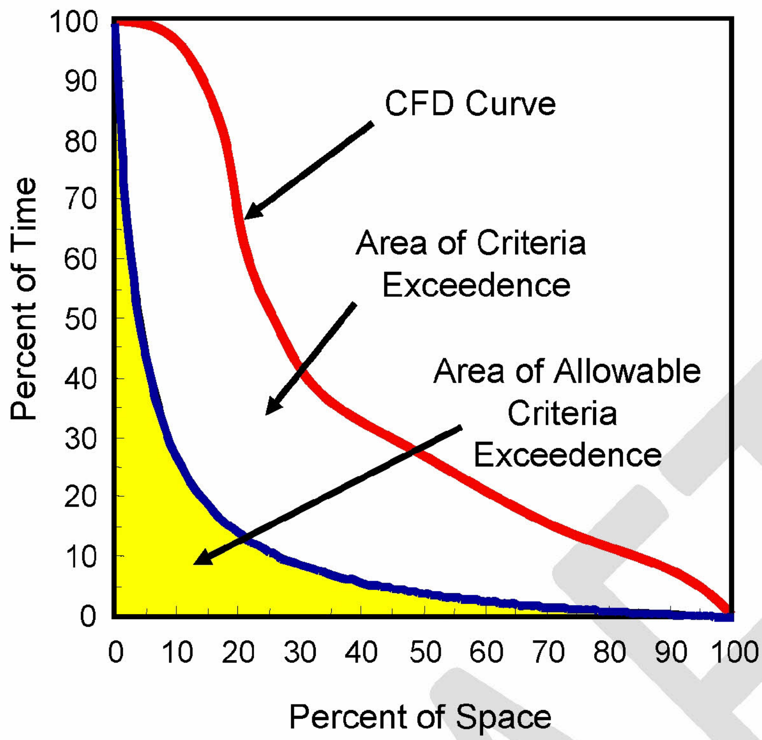
Using the Bay Water Quality Model, the SAV-water clarity WQS were assessed by starting with measured area of SAV in each Bay segment from the 1993–1995 critical period. On the basis of regressions of SAV versus load, the estimated SAV area because of a particular nutrient or sediment load reduction was estimated as described in Appendix H. Then the estimated water clarity acres from the Bay Water Quality Model were added in after adjustment by a factor of 2.5 to convert to the water clarity acres to *water clarity equivalent SAV acres* (Appendix H). Finally the water clarity equivalent SAV acres were added to the regression-estimated SAV acres and compared to the Bay segment-specific SAV WQS.

Note that when assessing attainment using monitoring data, only the SAV acres measurement is generally used because the number of Bay segments assessed with shallow-water clarity data are still limited. When projecting attainment using the Bay Water Quality model, the extrapolated measured SAV acres are added to the model-projected water clarity-equivalent SAV acres to determine total SAV acres (Appendix H).

6.2.2 Addressing Reduced Sensitivity to Load Reductions at Low Nonattainment Percentages

The Chesapeake Bay water quality criteria that the jurisdictions adopted into their respective WQS regulations provide for allowable exceedances of each set of DO, water clarity, SAV, and chlorophyll *a* criteria defined through application of a biological or default reference curve (USEPA 2003a). Figure 6-1 depicts that concept in yellow as allowable exceedance of the criterion concentration.

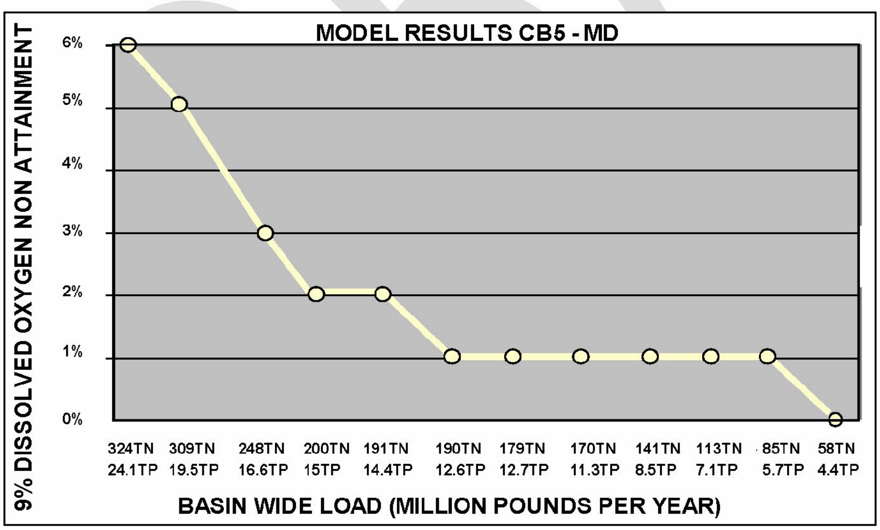
To compare model results with the WQS, the Bay Water Quality Model results for each scenario and for each modeled segment are analyzed to determine the percent of time and space that the modeled DO results exceed the allowable concentration. For any modeled result where the exceedance in space and time (shown in Figure 6-1) as the red line) exceeds the allowable exceedance (shown in Figure 6-1 as the yellow area), that segment is considered in nonattainment. The amount of nonattainment is shown in the figure as the area in white between the red line and the yellow area and is typically displayed in model results as percent of nonattainment for that segment. The amount of nonattainment is reported to the whole number percent.



Source: USEPA 2003a

Figure 6-1. Graphic comparison of allowable exceedance compared to actual exceedance.

Figure 6-2 below displays Bay Water Quality Model results showing percent nonattainment of the 30-day mean open-water DO criterion for various basinwide loading levels of the Maryland portion of the lower central Chesapeake Bay segment CB5MH_MD.



Source: Appendix Q.

Figure 6-2. Example of DO criteria nonattainment results from a wide range of nutrient load reduction model scenarios.

As can be seen in Figure 6-2, there is a notable improvement in the percent nonattainment as the loads are reduced until approximately 1 percent nonattainment. At a loading level of 190 million pounds per year TN and 12.6 million pounds per year TP, the 1 percent nonattainment is persistent through consecutive reductions in loading levels and remains consistent until a loading level of 58 million pounds per year TN and 4.4 million pounds per year of TP is reached. While this is one of the more extreme examples of persistent levels of 1 percent nonattainment, this general observation of persistent nonattainment at 1 percent is fairly common to the Bay Water Quality Model results (Appendix I).

This empirical observation is likely based on the geometry of the time and space-based assessment of the Bay WQS. An initial reduction made in the nutrient loads would be associated with an increase in attaining the WQS as shown in the green line in Figure 6-3. As reductions move toward attainment, the move toward the area of allowable criteria exceedance as shown by the light green line in Figure 6-3. Note that even though the reduced nutrient loads under the scenario represented by the light green line continue to reduce the time and space of WQS nonattainment, different rates of improvement exist at different portions of the curve. In this hypothetical example, the scenario represented by the light green line has reduced the time of exceedance well below the area of allowable exceedance, but the space component still showed a very low level of nonattainment.

The observation of a small, yet persistent percentage of model projected DO criteria nonattainment across a wide range of segments and designated uses, all of which are responding to nutrient load reductions, is an outcome of the criteria assessment methodology. Because this has been observed in a wide variety of different segments across all three designated uses—open-water, deep-water, and deep-channel—nonattainment percentages projected by the model rounded to 1 percent were considered to be in attainment for a segment's designated use for purposes of developing the Chesapeake Bay TMDL (Appendix I).

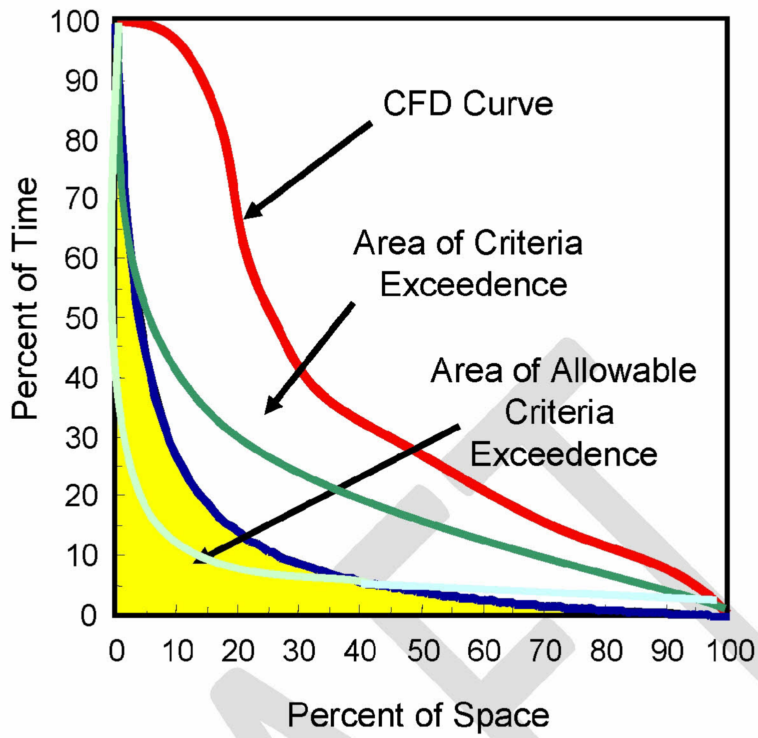


Figure 6-3. A graphical representation of how the persistent 1% nonattainment may arise in the criteria assessment of the Chesapeake Bay WQS.

A separate validation of the findings described above was undertaken to confirm that 1 percent was the correct percentage below which the designated use segment could be considered in attainment and is provided in Appendix L.

6.2.3 Margin of Safety

Under EPA's regulations, a TMDL is mathematically expressed as

TMDL = $\sum WLA + \sum LA + MOS$

where

- TMDL is the total maximum daily load for the water segment
- WLA is the wasteload allocation, or the load allocated to point sources
- LA is the load allocation, or the load allocated to nonpoint sources
- *MOS* is the margin of safety to account for any uncertainties in the supporting data and the model

The margin of safety (MOS) is the portion of the pollutant loading reserved to account for any lack of knowledge concerning the relationship between LAs and WLAs and water quality [CWA 303(d)(1)(c) and 40 CFR 130.7(c)(1)]. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection. On the basis of EPA guidance, the MOS can be achieved through two approaches (USEPA 1999): (1) implicitly incorporate the MOS by using conservative model assumptions to develop allocations; or (2) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. Table 6-2 describes different approaches that can be taken under the explicit and implicit MOS options.

Table 6-2. Different approaches available under the explicit and implicit MOS types

Type of MOS	Available approaches
Explicit	• Set numeric targets at more conservative levels than analytical results indicate. • Add a safety factor to pollutant loading estimates. • Do not allocate a portion of available loading capacity; reserve for MOS.
Implicit	• Use conservative assumptions in derivation of numeric targets. • Use conservative assumptions when developing numeric model applications. • Use conservative assumptions when analyzing prospective feasibility of practices and restoration activities.

Source: USEPA 1999

Implicit Margin of Safety for Nutrients

The Chesapeake Bay TMDL analysis is built on a foundation of more than two decades of modeling and assessment in the Chesapeake Bay and decades of Bay tidal waters and watershed monitoring data. The Bay Airshed, Watershed, and Water Quality models are state-of-the-science models, with several key models in their fourth or fifth generation of management applications since the early and mid-1980s. The use of those sophisticated models to develop the Bay TMDL, combined with application of specific conservative assumptions, significantly reduces EPA's uncertainty that the model's predictions of standards attainment is correct and, thereby, reduces the need for an explicit MOS for the Chesapeake TMDL.

The Chesapeake Bay TMDL for nutrients applies an implicit MOS in derivation of the DO and chlorophyll *a*-based nutrient allocations through the use of numerous conservative assumptions in the modeling framework. The three principal sets of conservative assumptions are as follows.

The basinwide allowable nutrient loads were determined on the basis of achieving a select set of deep-water and deep-channel DO standards in the mainstem Bay and adjoining embayments—middle (CB4MH) and lower (CB5MH) central Chesapeake Bay, Eastern Bay (EASMH), and lower Chester River (CHSMH). The Bay DO WQS in all the other 88 Bay segments will be achieved with reductions less than (i.e., higher loadings) that needed for attainment of these deep-water and deep-channel DO WQS, often much less.

The critical period selected (as described above) was based on a 3-year period that represented fairly protective conditions, representing a high-flow condition that is expected approximately only once in 10 years. This high-flow period is caused by high rainfall, which in turn causes high nonpoint source loads. The combination of requiring achievement of the Bay WQS first across a 3-year period, not a single year, and the decadal scale return frequency for the hydrological conditions represented by the 3-year period, puts in place an important set of conservative assumptions supporting an implicit MOS. In other words, because the TMDL identifies loading to achieve WQS during the critical period (with high rainfall, high streamflows, and high NPS loading), the TMDL provides even more protection for water quality during less critical (e.g., lesser rainfall) years.

The allocation scenario model run assumes that all point sources are discharging at their maximum (allocated) load in a given year when, in fact, the facilities will almost always be operating and discharging at level below their maximum load limits. For example, when assigned a concentration-based limit, municipal wastewater treatment facilities will generally seek to operate in a manner to provide themselves a buffer in attaining that limit—i.e., they will discharge less than the limit, to avoid being on the edge of noncompliance. That is true of regulated limits for many parameters and is easily verified using discharge monitoring report (DMR) data. Therefore, each permittee will actually be discharging at loads much less than their allocated load, providing an implicit MOS for the TMDL.

Explicit Margin of Safety for Sediment

The Bay TMDL allocations for sediment used a variable explicit MOS. EPA acknowledges that the science supporting the estuarine modeling simulation of the transport and resuspension for sediments is not as strong as that for nutrients.[1] Because of that higher degree of uncertainty, EPA determined that an implicit MOS was not appropriate for sediment unlike in the case of nutrients. As described in section 6.4.2, the sediment allocations were established at a loading level that was at varying levels below the maximum loading levels that the Bay water quality model predicted would achieve the SAV WQS for most Bay segments. In other words, EPA established the Bay TMDL allocations primarily at levels that were attained as a result of the management controls proposed in the state WIPs for controlling nitrogen and phosphorus. Therefore, the management controls yield sediment loadings (and allocations) with a variable MOS from one Bay segment to another.

The explicit MOS is appropriate for sediment because the Bay Water Quality Model projected that many Bay segments would be in attainment with the SAV/water clarity standards at the current (2009) loading levels. In contrast, recent data from the Bay-wide SAV aerial survey and limited, shallow-water quality monitoring data showed that most Bay segments were not in attainment with the SAV restoration acreages goals or water clarity criteria. That observation demonstrates that the Bay Water Quality Model was overly optimistic in its simulation of SAV acreages and water clarity in the shallows and, therefore, promotes the need for an explicit MOS to ensure the sediment allocations would achieve the Bay jurisdictions' SAV/water clarity WQS.

6.2.4 Temporary Reserve

EPA has included a separate Temporary Reserve, for both nitrogen and phosphorus, of 5 percent of the allocated load for each jurisdiction that will be applied for purposes of WIP development and incorporating *contingency actions* (USEPA 2010f). EPA requested the jurisdictions incorporate contingency actions into their WIPs as a separate suite of actions to be undertaken if the 2011 refinements to the Phase 5.3 Chesapeake Bay Watershed Model result in draft allocations lower than those provided with EPA's July 1, 2010, letter (USEPA 2010f). Contingency actions were to be described in similar detail to implementation actions included in

[1] Copies of the Chesapeake Bay Water Quality Sediment Transport Model Review Panel's (convened by the CBP's Scientific and Technical Advisory Committee) reports are at http://www.chesapeakebay.net/committee_msc_projects.aspx?menuitem=16525#peer.

each jurisdiction's WIPs for the 2017–2025 time frame. EPA identified the Temporary Reserve to lessen the effect of any potential revisions to draft nutrient allocations (resulting from the two model refinements) that may be lower than the draft allocations assigned within the July 1, 2010, letter (including the Temporary Reserve). No jurisdiction has requested a temporary reserve allocation in their draft WIP. EPA has considered this and has not included a temporary reserve in any of the allocation scenarios set forth in Section 9. EPA is seeking comment on whether to include such a temporary reserve in the final TMDL allocations.

The additional 5 percent Temporary Reserve was derived on the basis of two main factors. The basinwide nitrogen draft allocation changed approximately 5 percent when transitioning from Phase 5.2 of the Chesapeake Bay Watershed Model (approximately 200 million pounds in fall 2009) to Phase 5.3 (approximately 190 million pounds currently), and therefore, the additional model revisions are not expected to result in changes to draft allocations that are any greater than that extent. Very preliminary analyses suggest that the two forthcoming refinements to the Bay Watershed Model will alter basinwide nutrient draft allocations by 5 percent or less.

Depending on the results of the 2011 Phase 5.3 Watershed Model refinements, the Temporary Reserve will be revised or removed as appropriate during the 2011 Phase II WIP development process (USEPA 2010g). In parallel, if needed, jurisdictions can submit for public comment and EPA approval any proposed modifications to the Chesapeake Bay TMDL draft allocations (USEPA 2010f). No jurisdiction draft WIPs has reserved such an allocation. The temporary reserves are identified in Table 6-3 below.

Table 6-3. Nitrogen and phosphorus temporary reserves by Chesapeake Bay watershed jurisdiction.

Jurisdiction	Nitrogen temporary reserve (million pounds per year)	Phosphorus temporary reserve (million pounds per year)
Pennsylvania	3.84	0.14
Maryland	1.95	0.14
Virginia	2.67	0.27
District of Columbia	0.12	0.01
New York	0.41	0.03
Delaware	0.15	0.01
West Virginia	0.23	0.04
Total temporary reserve	**9.37**	**0.63**

Source: USEPA2010g.

6.2.5 Daily Loads

Consistent with the D.C. Circuit Court of Appeals decision in *Friends of the Earth, Inc. v. EPA*, EPA is expressing its draft Chesapeake Bay TMDL in terms of daily time increments (446 F.3d 140 (D.C. Cir. 2006)). Specifically, the Chesapeake Bay TMDL has developed a maximum daily and seasonal load calculation for nitrogen, phosphorus and sediment for each of the 92 Chesapeake Bay main-stem and tidal segments. However, EPA also recognizes that it is appropriate and necessary to identify non-daily allocations in TMDL development despite the need to also identify daily loads. In an effort to fully understand the physical and chemical dynamics of a waterbody, many TMDLs are developed using methodologies that result in the development of pollutant allocations expressed in monthly, seasonal or annual time periods consistent with the applicable WQS.

EPA encourages TMDL developers to continue to apply accepted and reasonable methodologies when calculating TMDLs for impaired waterbodies, and to use the most appropriate averaging period for developing allocations based on factors such as available data, watershed and waterbody characteristics, pollutant loading considerations, applicable standards, and the TMDL development methodology. Consistent with this policy, the Chesapeake Bay TMDL was developed to reflect a statistical expression of a maximum daily load applicable to *each day* of the year and as a *seasonal* representation based on daily maximum values. While only the daily maximum loads are provided for each tidal segment using the output of the Bay TMDL models, the methodology is described here for deriving the seasonal daily maximum loadings.

The process for deriving daily loads for TMDLs is often based on non-daily allocations, such as the annual expression in the Chesapeake Bay TMDL. It builds on the data and information used in the non-daily TMDL analysis, supplementing that data as necessary and identifying a daily load dataset—a population of continuous or frequent allowable daily loads that meet the loading capacity and therefore represent maintenance of WQS. In the Chesapeake Bay TMDL, watershed and water quality dynamic models were used that generated daily load datasets as routine model output.

Approach for Expressing the Maximum Daily Loads

The methodology applied to calculate the expression of the maximum daily loads and associated wasteload and load allocations in the Chesapeake Bay TMDL is consistent with the approach contained in EPA's published guidance. *Establishing TMDL "Daily" Loads in Light of the Decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA, et al., No. 05-5015, (April 25, 2006) and Implications for NPDES Permits*, dated November 15, 2006 (USEPA 2006). Additionally, the analytical approach selected in the Bay TMDL is similar to the wide range of technically sound approaches and the guiding principles and assumption described in the technical document *Options for the Expression of Daily Loads in TMDLs* (USEPA 2007c). Those principles and assumptions are:

1. Methods and information used to develop the daily load should be consistent with the approach used to develop the loading analysis.
2. The analysis should avoid added analytical burden without providing added benefit.
3. The daily load expression should incorporate terms that address acceptable variability in loading under the long-term loading allocation. Because many TMDLs are developed for precipitation-driven parameters, it may be appropriate to represent the daily load with a range to account for allowable differences in loading due to seasonal or flow-related conditions (e.g., daily maximum and daily median).
4. The specific application (e.g., data used, values selected) should be based on knowledge and consideration of site-specific characteristics and priorities.
5. The TMDL analysis on which the daily load expression is based should fully meet the EPA requirements for approval, be appropriate for the specific pollutant and waterbody type, and result in attainment of water quality criteria.

Computing the Daily Maximum Loads and the Seasonal Daily Maximum Loads

Daily loads are derived for each of the 92 tidal segments and for each of the three pollutants as a direct product of the Chesapeake Bay TMDL and associated modeling. This modeling output serves as the starting point for the maximum daily load expression and the maximum seasonal load expression. These daily maximum loads and seasonal daily maximum loads are a function of the ten-year continuous simulation produced by the paired Bay Watershed-Bay Water Quality models. This modeling approach allows for the daily maximum load expression to be taken directly from the output of the TMDL itself, assuring a degree of consistency between the daily maximum load calculation and the loads necessary to meet water quality standards included in the final TMDL. That is, this methodology uses the annual allocations derived through the modeling/TMDL analysis, and converts those annual loads to daily maximum loadings.

Both the Chesapeake Bay TMDL daily maximum load and seasonal daily maximum load represents the 95th percentile of the distribution to protect against the presence of anomalous outliers. This expression implies a 5 percent probability that a daily or seasonal daily maximum load will exceed the specified value under the TMDL condition. The steps employed to compute the Daily and Seasonal Maximum Load for each segment are:

1. Calculate the annual average loading for each of the 92 tidal segments, (this would be the annual loading under the TMDL/allocation condition)
2. Calculate the 95th percentile of the daily loads delivered to each of the 92 tidal segments (using the same loading condition as step 1)
3. Calculate the Annual/Daily Maximum ratio (ADM) for each of the 92 tidal segments by dividing the annual average load by the daily maximum load,
4. Calculate a Baywide ADM by computing a load weighted average of all of the 92 tidal segments ADM ratios,
5. Apply the Baywide ADM to all of the annual TMDLs, WLAs and LAs in each of the 92 tidal segments contained in the TMDL to calculate the daily maximum loads,
6. Using the approach described in 1-5 above, calculate a Baywide ADM for each season for each of the 92 tidal segments.

Using this method, the Annual/Daily Maximum Loading ratios listed in Table 6-4were developed.

Table 6-4. Annual/Daily Maximum (ADMs) for calculating daily maximum loads-

	Winter	Spring	Summer	Fall	All Year
TN	123.7	80.9	337.1	210.9	123.6
TP	95.8	60.1	260.7	141.2	98.2
TSS	96.5	58.0	384.7	158.1	100.3

It should be noted that a statistical expression of a daily load is just that, an expression of the probability that a specific maximum daily load will occur in a given segment for a specific pollutant. There will be situations where the maximum daily load allocation for some segments will exceed the TMDL allocation, and in other segments the maximum daily load allocation will be less than the TMDL allocation. However, the magnitude of the TMDL allocations was established to assure the attainment of all applicable water quality standards in each of the 92 tidal segments.

In addition to the maximum daily load provided for each of the 92 tidal segments in Section 9, the reader can readily calculate a daily maximum load expressed in seasonal terms for any segment, WLA, or LA of interest. This seasonal expression reflects a temporally variable target because the various pollutant sources (point and nonpoint) vary significantly by month and by season. Additionally, a daily maximum load expressed in seasonal terms for each segment is also informative because the recently adopted water quality standards are also expressed with a degree of temporal specificity. For example, the Migratory Fish Spawning and Nursery designated uses require a 7 day mean dissolved oxygen value of 6 mg/L, with an instantaneous minimum of 5 mg/L in the time period February 1 through May 31.

The expression of maximum daily loads for individual wasteload and load allocations proposed in this draft TMDL represent EPA's best efforts to date to calculate nitrogen, phosphorus, and sediment allocations, informed by the jurisdictions' watershed implementation plans and other elements of the TMDL accountability framework, necessary to implement all applicable Bay water quality standards with seasonal variations, considering critical conditions and with a margin of safety. EPA invites comment on this approach or alternative approaches for calculating daily maximum load values.

6.3 Establishing Allocation Rules

An early step in the process for developing the Bay TMDL, especially for nutrients, is to determine the allowable loading from jurisdictions and major basins draining to the Bay. There are limitless combinations of loadings from the various jurisdictions and basins that would achieve this objective. As a result, an equitable approach must be employed to apportion the allowable loading among the jurisdictions. This subsection describes the process used for this purpose in the Bay TMDL.

6.3.1 Nutrient Allocation Methodology

Nutrients from sources well up within the Chesapeake Bay watershed affect the condition of local receiving waters and affect tidal water quality conditions far downstream, hundreds of miles away in some cases. For example, the middle part of the mainstem Chesapeake Bay is affected by nutrients from all parts of the Bay watershed. A key objective of the nutrient LA methodology was to find a process, based on some expression of an equitable distribution of loads for which the basinwide load for nutrients could be distributed among the basin-jurisdictions. This section describes the specific processes involved in allocating the nutrients loads necessary to meet the jurisdictions' Chesapeake Bay DO and chlorophyll *a* WQS. While many alternative processes were explored (see Appendix K), only the processes determined to be appropriate by EPA and agreed upon by five of the seven Bay watershed jurisdictional partners are described here.

Principles and Guidelines

The nutrient basin-jurisdiction allocation methodology was developed to be consistent with the following guidelines adopted by the partnership:

- The allocated loads should protect the living resources of the Bay and its tidal tributaries and result in all segments of the Bay mainstem, tidal tributaries, and embayments meeting WQS for DO, chlorophyll a, and water clarity.
- Major river basins that contribute the most to the Bay water quality problems must do the most to resolve those problems (on a pound per pound basis).
- All tracked and reported reductions in nutrient loads are credited toward achieving final assigned loads.

A number of critical concepts are important in understanding the major river basin by jurisdiction nutrient allocation methodology. They include the following:

- Accounting for the geographic and source loading influence of individual major river basins on tidal water quality termed relative effectiveness
- Determining the controllable load
- Relating *controllable load* to *relative effectiveness* to determine the allocations of the basinwide loads to the basin-jurisdictions

The following subsections further describe the above concepts and how they directly affect the Chesapeake Bay TMDL.

Accounting for Relative Effectiveness of the Major River Basins on Tidal Water Quality

Relative effectiveness accounts for the role of geography on nutrient load changes and, in turn, Bay water quality. Because of various factors such as in-stream transport and nutrient cycling in the watershed, a given management measure will have a different level of effect on water quality in the Bay depending on the location of its implementation (USEPA 2003b). For example, the same control applied in Williamsport, Pennsylvania, will have less of an effect than one applied in Baltimore, Maryland.

A relative effectiveness assessment evaluates the effects of both estuarine transport (location of discharge/runoff loading to the Bay) and riverine transport (location of the discharge/runoff loading in the watershed). EPA determined the relative effectiveness of each contributing river basin in the overall Bay watershed on DO in several mainstem Bay segments and the lower Potomac River by using the Bay Water Quality Model to run a series of *isolation* runs and using the watershed model to estimate attenuation of load through the watershed.

From the relative estuarine effectiveness analysis, several things are apparent. Northern, major river basins have a greater relative influence than southern major river basins, because of the general circulation patterns of the Chesapeake Bay (up the eastern shore, down the western shore). Water and nutrients from the most southern river basins of the James and York rivers have relatively less influence on mainstem Bay water quality because of their proximity to the mouth of the Bay. The counter-clockwise circulation of the lower Bay also tends to wash nutrient loads from these larger southern river basins out of the Bay mouth, because they are on the western side of the Bay. That same counter-clockwise circulation tends to sweep loads from the lower Eastern Shore northward.

River basins whose loads discharge directly to the mainstem Bay, like the Susquehanna, tend to have more effect on the mainstem Bay segments than basins with long riverine estuaries (e.g., the Patuxent and Rappahannock rivers). The long riverine estuaries provide nutrient attenuation (burial and denitrification) before the waters reaching the mainstem Chesapeake Bay. The size of a river basin is uncorrelated to its relative influence, though larger river basins, with larger loads, have a greater absolute effect. The upper tier of relative effect in the three mainstem segments includes the largest (Susquehanna) and the smallest (Eastern Shore Virginia) river basins, both directly discharging into the Bay without intervening river estuaries to attenuate loads, and both *up current* to the deep-channel region of the mainstem Chesapeake Bay, again, given the Bay circulation pattern that moves water up the Eastern Shore, and down the Western Shore.

The estuarine effectiveness is estimated by running a series of Bay Water Quality Model scenarios holding one major river basin at E3 loads and all other major river basins at calibration levels. For each scenario, the increase in the 25th percentile DO concentration during the summer criteria assessment period in the critical segments CB3MH, CB4MH, and CB5MH for deep-channel and CB3MH, CB4MH, CB5MH, and POTMH for deep-water was recorded. The 25th percentile was selected as the appropriate metric as indicative of a change in low DO. The riverine effectiveness is calculated as the fraction of load produced in the watershed that is delivered to the estuary. It is estimated as an output of the watershed model. For more details on this method, see Appendix M.

Absolute estuarine effectiveness accounts for the role of both total loads and geography on pollutant load changes to the Bay. The absolute estuarine effectiveness of a contributing river basin, measured separately both above and below the fall line, is the change in 25th percentile DO concentration that results from a single basin changing from calibration conditions to E3. For example, if the 25th percentile DO in the deep water of the lower Potomac River segment POTMH moves from 5 mg/L to 5.3 mg/L from a change in loads from calibration to E3 in the Potomac above fall line basin, the absolute estuarine effectiveness is 0.3 mg/L. Comparing the absolute estuarine effectiveness among basins helps to identify which major river basins have the greatest effect on WQS.

Relative estuarine effectiveness is defined as absolute estuarine effectiveness divided by the total load reduction, delivered to tidal waters, necessary to gain that water quality response. For example, if the load reduction in the Potomac above fall line basin was 30 million pounds of pollutant to get a 0.3 mg/L change in DO concentration, the relative estuarine effectiveness is 0.01 mg/L per million pounds. The higher the relative estuarine effectiveness, the less reduction required to achieve the change in status. The relative estuarine effectiveness calculation is an attempt to isolate the effect of geography by normalizing the load on a per pound basis. Comparing the relative estuarine effectiveness among the major river basins shows the resulting gain in attainment from performing equal pound reductions among the major river basins.

Riverine attenuation also has an effect on overall effectiveness. Loads are naturally attenuated or reduced as they travel through long free-flowing river systems, making edge-of-stream loads in headwater regions less effective on a pound-for-pound basis than edge-of-stream loads that take place nearer tidal waters in the same river basin. The watershed model calculates delivery factors as the fraction of edge-of-stream loads that are delivered to tidal waters. The units of riverine attenuation are delivered pound per edge-of-stream pound.

Multiplying the estuarine relative effectiveness (measured as DO increase per delivered pound reduction) by the riverine delivery factor (measured as delivered pound per edge-of-stream pound) gives the overall relative effectiveness in DO concentration increase per edge-of-stream pound. The relative estuarine effectiveness is the same for nitrogen or phosphorus, while the riverine delivery is different, so the overall relative effectiveness is calculated separately for nitrogen and phosphorus. **Error! Reference source not found.** gives the overall relative effectiveness for nitrogen and phosphorus for the watershed jurisdictions by major river basin for above and below the fall line.

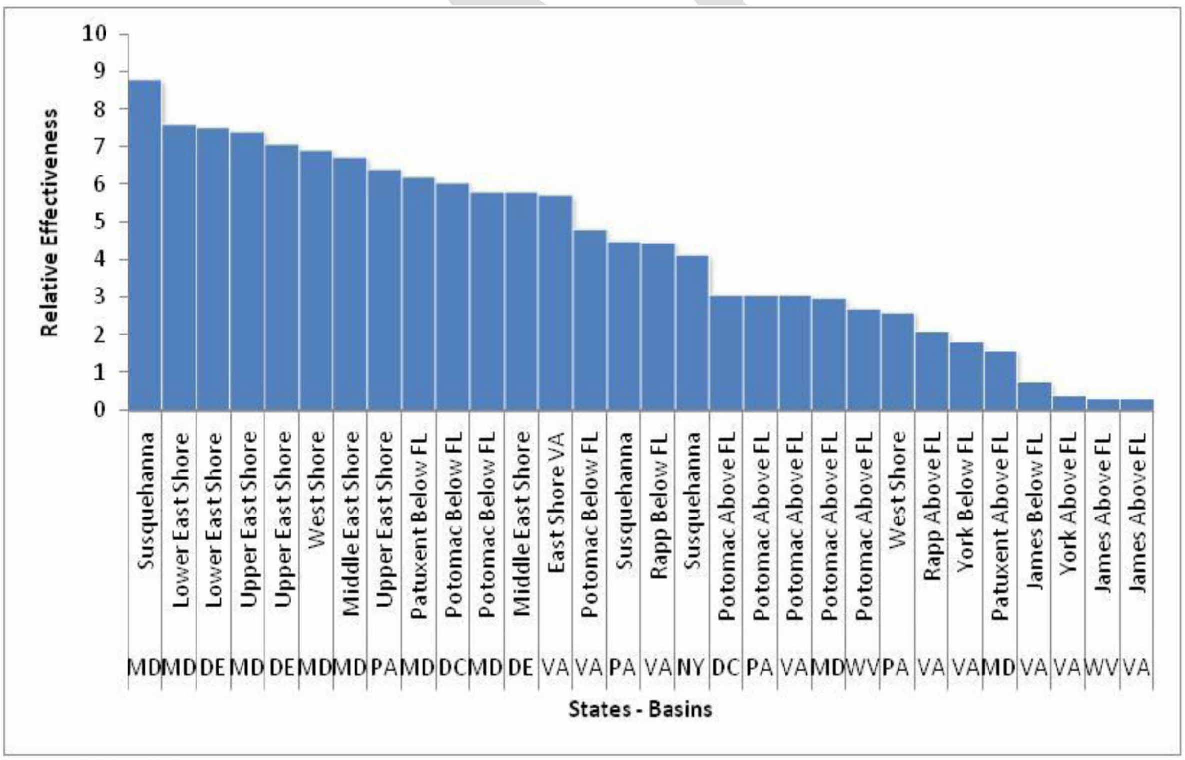
The relative effectiveness numbers are separate for wastewater treatment plants and all other sources. The distinction is made because the allocation method treats them separately. The difference in relative effectiveness is due to the geographic location of the sources. For example, in the Maryland western shore basin, the majority of the wastewater treatment load is discharged directly to tidal waters, whereas a significant fraction of all other sources are upstream, including areas that are above reservoirs with very low delivery factors.

Table 6-5. Relative effectiveness (measured as DO concentration per edge-of-stream pound reduced) for nitrogen and phosphorus for watershed jurisdictions by major river basin and above and below the fall line

Jurisdiction	Basin	WWTP Nitrogen	All Other Nitrogen	WWTP Phosphorus	All Other Phosphorus
District of Columbia	Potomac above Fall Line	6.09	6.09	3.08	3.08
District of Columbia	Potomac below Fall Line	6.17	5.15	6.17	5.62
Delaware	Lower East Shore	7.93	7.30	7.97	7.46
Delaware	Middle East Shore	4.13	4.74	5.51	5.83
Delaware	Upper East Shore	6.75	6.75	7.10	7.10
Maryland	Lower East Shore	7.88	7.37	7.89	7.55
Maryland	Middle East Shore	6.91	6.49	6.92	6.71
Maryland	Patuxent above Fall Line	1.89	1.25	1.66	1.58
Maryland	Patuxent below Fall Line	6.38	6.20	6.38	6.10
Maryland	Potomac above Fall Line	3.32	3.25	2.99	2.99
Maryland	Potomac below Fall Line	6.17	4.86	6.12	5.75
Maryland	Susquehanna	9.39	8.68	9.11	8.77
Maryland	Upper East Shore	7.49	7.27	7.49	7.40
Maryland	West Shore	7.83	4.98	7.68	6.13
New York	Susquehanna	5.60	4.58	4.25	4.11
Pennsylvania	Potomac above Fall Line	2.10	1.98	3.08	3.08
Pennsylvania	Susquehanna	6.99	6.44	4.38	4.58
Pennsylvania	Upper East Shore	5.50	5.95	6.12	6.47
Pennsylvania	West Shore	2.23	2.23	2.61	2.61

Jurisdiction	Basin	WWTP Nitrogen	All Other Nitrogen	WWTP Phosphorus	All Other Phosphorus
Virginia	East Shore VA	5.72	5.72	5.72	5.72
Virginia	James above Fall Line	0.23	0.25	0.33	0.31
Virginia	James below Fall Line	0.79	0.61	0.79	0.70
Virginia	Potomac above Fall Line	1.45	1.97	3.08	3.08
Virginia	Potomac below Fall Line	5.54	3.54	5.49	4.62
Virginia	Rappahannock above Fall Line	1.05	0.83	2.10	2.10
Virginia	Rappahannock below Fall Line	4.48	4.41	4.48	4.47
Virginia	York above Fall Line	0.37	0.31	0.43	0.40
Virginia	York below Fall Line	1.85	1.77	1.85	1.82
West Virginia	James above Fall Line	0.06	0.06	0.34	0.34
West Virginia	Potomac above Fall Line	1.34	1.72	2.12	2.89

Figure 6-4 illustrates graphically the relative effectiveness scores for nitrogen of the major river basins provided in **Error! Reference source not found.** in descending order.



Source: Table 6-5.

Figure 6-4. Relative effectiveness for nitrogen for the watershed jurisdictions and major rivers basins, above and below the fall line, in descending order.

Figure 6-5 and Figure 6-6 provide additional graphical illustration of the relative effectiveness concept for all the basins in the watershed related to nitrogen and phosphorus loading, respectively. The figures illustrate that, on a per pound basis, a large disparity exists among basin loads on the effect of DO concentrations in the Bay. Generally, the Northern and Eastern river basins have a greater effect on water quality.

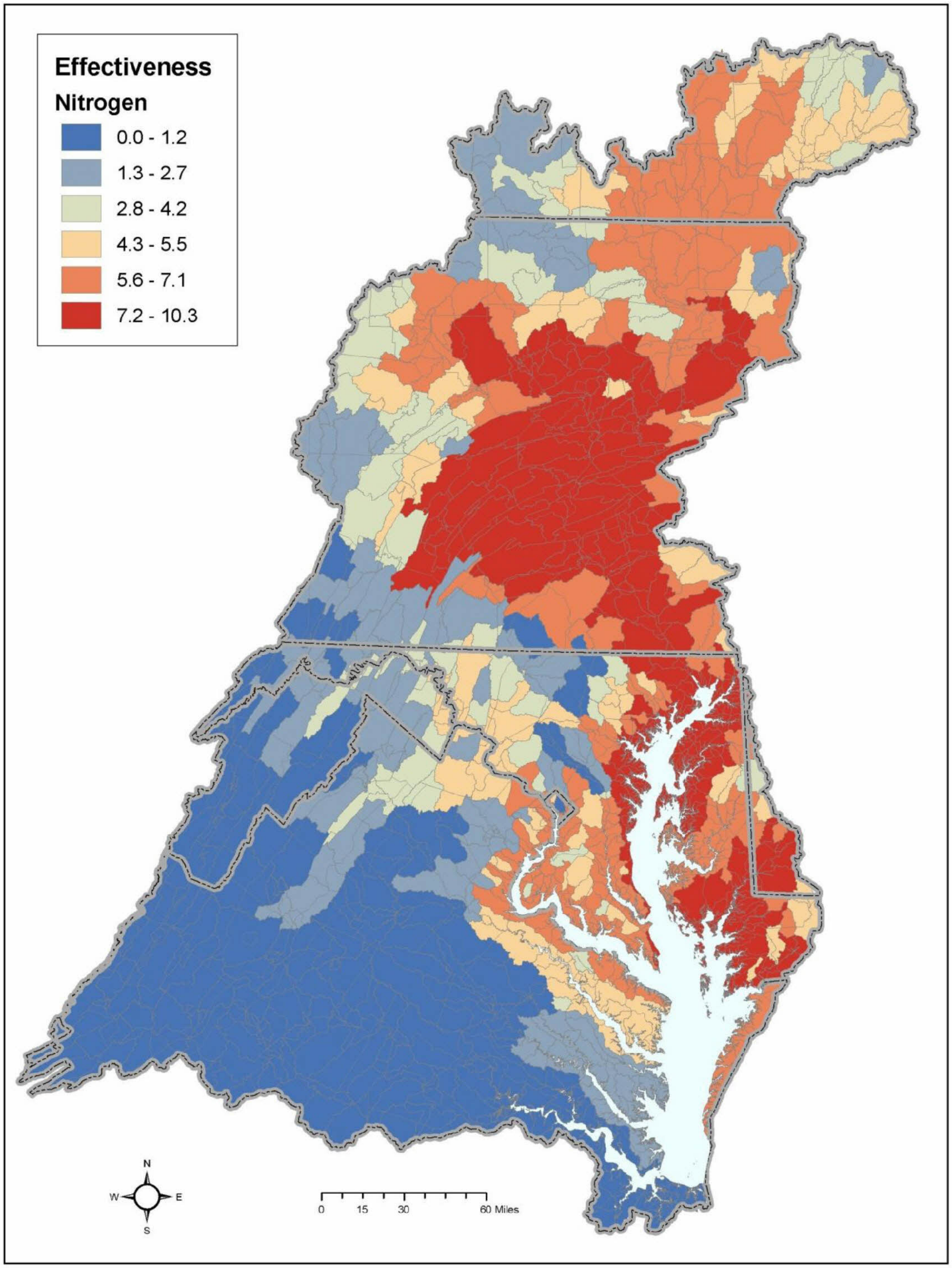


Figure 6-5. Relative effectiveness illustrated geographically by subbasins across the Chesapeake Bay watershed for nitrogen.

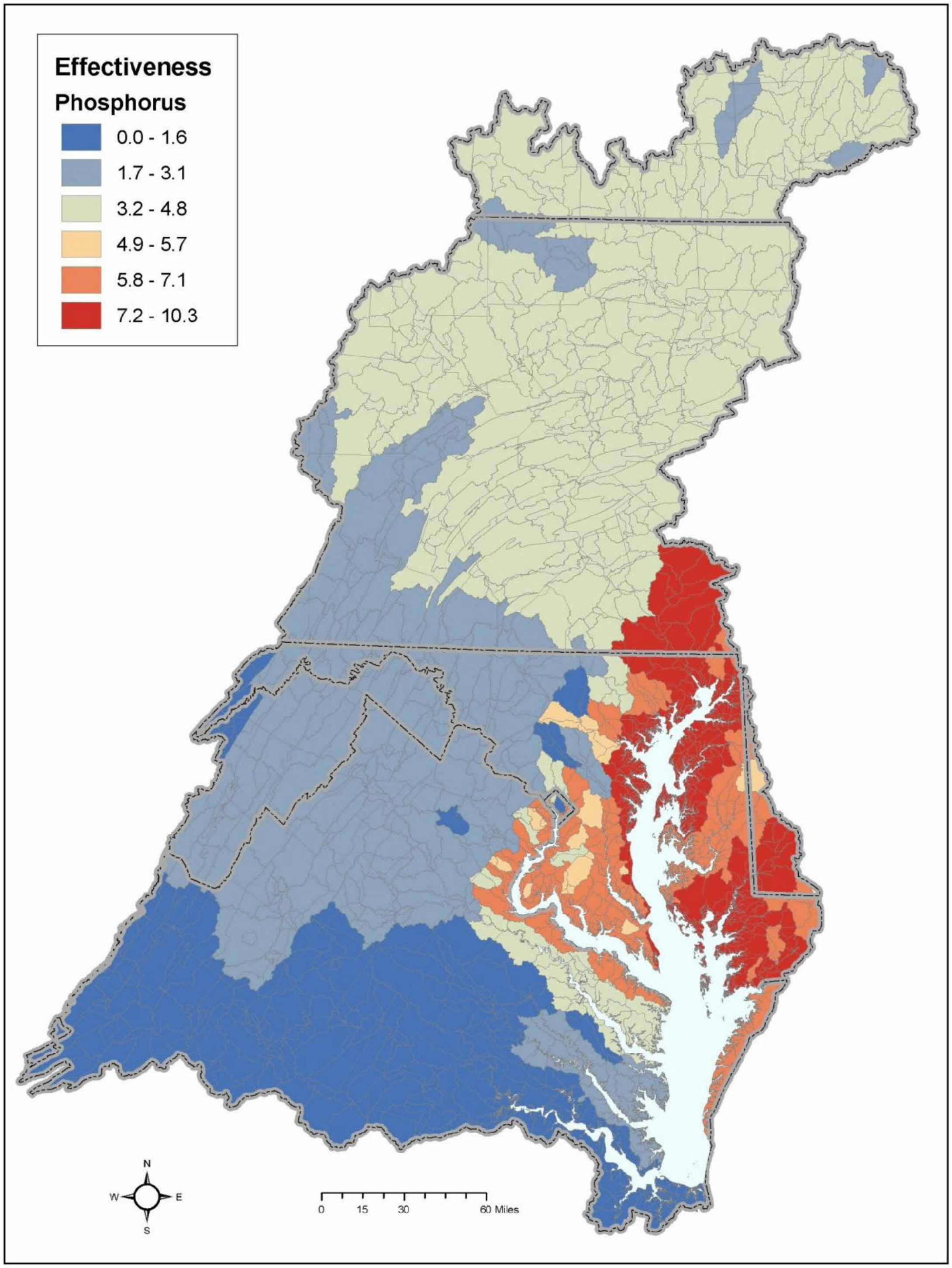


Figure 6-6. Relative effectiveness for illustrated geographically by subbasins across the Chesapeake Bay watershed for phosphorus.

Determining Controllable Load

Modeling in support of developing the Chesapeake Bay TMDL employs two theoretical scenarios that help to illustrate the load reductions in the context of a *controllable* load.

The *No Action* scenario is indicative of a theoretical *worst case* loading situation in which no controls exist to mitigate nutrient and sediment loads from any sources. It is specifically designed to support equity among basin-jurisdiction allocations in that the levels of all control technologies and BMP and program implementation are at *baseline* conditions.

The E3 scenario represents a *best case* possible situation, where all possible BMPs and available control technologies are applied to land given human and animal populations and wastewater treatment facilities are represented at highest technologically achievable levels of treatment regardless of costs. Again, it considers equity among the allocations in that the levels of control technologies and practice and program implementation are the same across the entire watershed.

The gap between the No Action scenario and the E3 scenario represents the maximum theoretical controllable load reduction that is achievable under the control technologies covered under the E3 scenario. These and other key reference scenarios are defined and documented in detail in Appendix J.

Each scenario can be run with any given year's land use representation. The year 2010 was selected as the base year because it represents conditions at the time the Bay TMDL is developed. Thus, the 2010 No Action scenario represents loads resulting from the mix of land uses and point sources present in 2010 with no effective controls on loading, while the 2010 E3 scenario represents the highest technically feasible treatment that could be applied to the mix of land use-based sources and permitted point sources in 2010 (Table 6-6).

The anthropogenic, *controllable* load is determined by subtracting the basinwide E3 load from the basinwide No Action load. Model scenarios run to show results of various loading reduction management options can be expressed as a percentage of E3 to compare and contrast the relative level of effort between scenarios.

Table 6-6. Pollutant sources as defined for the No Action and E3 model scenarios

Model source	Scenario: No Action	Scenario: E3 = Everyone Everything Everywhere
Land uses	No BMPs applied to the land	All possible BMPs applied to land given current human and animal population and land use
Point sources	Significant municipal WWTPs Flow = design flows TN = 18 mg/L TP = 6 mg/L BOD = 30 mg/L DO = 4.5 mg/L TSS = 15 mg/L Significant industrial dischargers Flow = design flows TN = highest recorded TP = highest recorded BOD = 30 mg/L DO = 4.5 mg/L TSS = 15 mg/L Non-significant municipal WWTPs Flow = existing flows TN = 18 mg/L TP = 6 mg/L BOD = 30 mg/L DO = 4.5 mg/L TSS = 15 mg/L	Significant municipal WWTPs Flow = design flows TN = 3 mg/L TP = 0.1 mg/L BOD = 3 mg/L DO = 6 mg/L TSS = 5 mg/L Significant industrial dischargers Flow = design flows TN = 3 mg/L TP = 0.1 mg/L BOD = 3 mg/L DO = 6 mg/L TSS = 5 mg/L Non-significant municipal WWTPs Flow = existing flows TN = 8 mg/L TP = 2 mg TP/l BOD = 5 mg/L DO = 5 mg/L TSS = 8 mg/L
CSOs	Flow = 2003 base condition flow TN = 18 mg/L TP = 6 mg/L BOD = 200 mg/L DO = 4.5 mg/L TSS = 45 mg/L	Full storage and treatment of CSOs
Atmospheric deposition	1985 Air Scenario	2030 Air Scenario, max reductions

Source: Appendix J
Note: BOD = biological oxygen demand; DO = dissolved oxygen; TN = total nitrogen; TP = total phosphorus; TSS = total suspended solids

Relating Relative Impact to Needed Controls (Allocations)

To apply the allocation methodology, loads from each major river basin were divided into two categories—wastewater and all other sources (Figure 6-7). The rationale for this separate accounting is the higher likelihood of achieving greater load reductions for the wastewater sector than for other source sectors (Appendix K). In addition there was a wide disparity between basin and jurisdictions on the fraction of the load coming from the wastewater sector as opposed to other sectors. So, this disparity is addressed in having a separate accounting for the wastewater sector from the other sectors in the allocation methodology. Wastewater loads included all major and minor municipal, industrial and CSO discharges. Then lines were drawn for each of the two source categories such that the addition of the two lines would add up to the basinwide nutrient loading targets for nitrogen and phosphorus.

Using the general methodology described above, the Bay Program partners considered many different combinations of wastewater and *other source'* controls and slopes of the lines on that allocation graph (Appendix K). After discussing these options at length, the following graph specifications were generally accepted by the partners and determined to be appropriate by EPA.

The wastewater line was set first and would be a *hockey stick* shape with load reductions increasing with relative effectiveness until a maximum percent controllable load was reached.

- For nitrogen
    - The maximum percent controllable load was 90 percent, corresponding to an effluent concentration of 4.5 mg/L.
    - The minimum percent controllable load was 67 percent, corresponding to an effluent concentration of 8 mg/L.
- For phosphorus
    - The maximum percent controllable load was 96 percent, corresponding to an effluent concentration of 0.22 mg/L.
    - The minimum percent controllable load was 85 percent, corresponding to an effluent concentration of 0.54 mg/L.
- For the nitrogen and phosphorus wastewater lines, any relative effectiveness value that was at least half as large as the maximum was given the maximum percent controllable. The minimum value was assigned to a relative effectiveness of zero, and all values of relative effectiveness between zero and half of the maximum value were assigned interpolated percentages (Figure 6-7).

The *other sources* line was set at a level that was necessary to achieve the basinwide load needed for achieving the DO standards in the middle mainstem Bay and lower tidal Potomac River. This line was set at a slope such that there was a 20 percent overall slope, ranging from 56 percent of controllable loads for basins with low relative effectiveness to 76 percent of controllable loads for basins with high relative effectiveness for nitrogen (Figure 6-7).

For each category—wastewater and all other sources—loads are aggregated by major basin and reductions are assigned according to the specific river basin's relative effectiveness. The graph in Figure 6-7 illustrates the methodology for the total nitrogen target load of 190 million lbs per year.

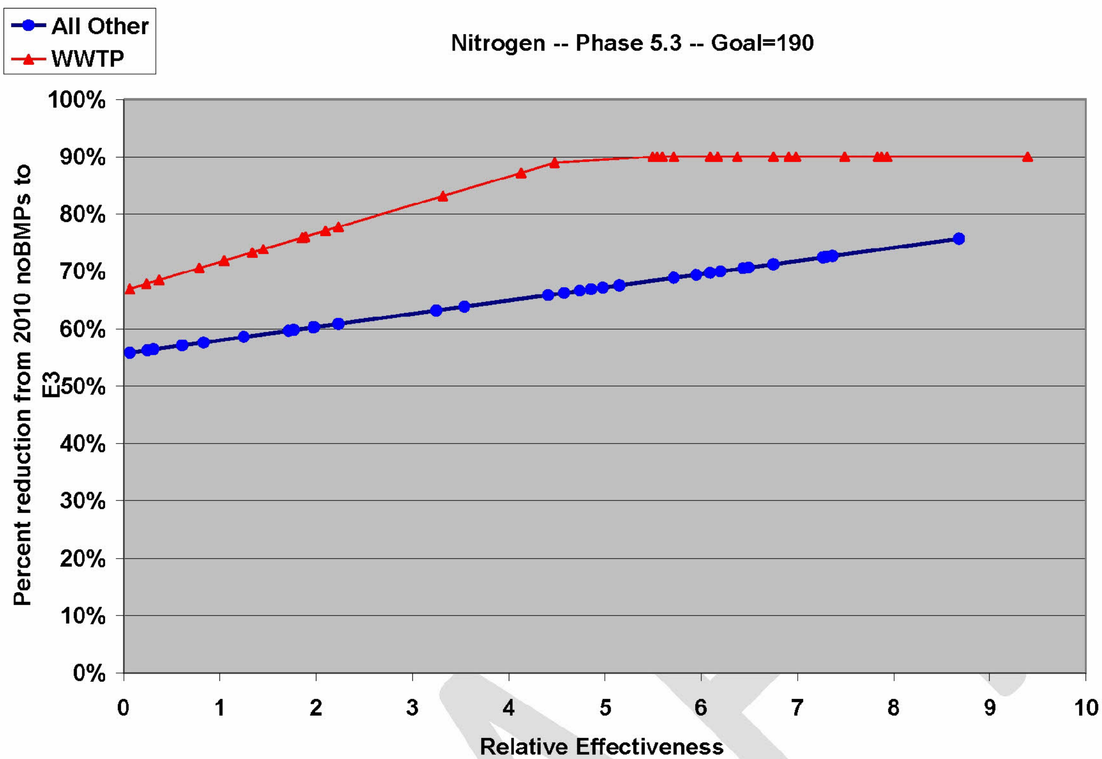


Figure 6-7. Allocation methodology example showing the *hockey stick* and straight line reductions approaches, respectively, to wastewater (red line) and all other sources (blue line) for nitrogen.

6.3.2 Sediment Allocation Methodology

The methodology used for allocating sediment loads to major river basins and jurisdictions for sediment was much different than the methodology used for nutrients. That is because sediment has a much more localized effect than nutrients and, therefore, for sediment, the immediate subbasin (i.e., the Chester River) has a large influence on the water clarity and SAV growth in that subbasin. So for sediment, the allocated load is driven primarily from the local subbasin that is contributing sediment to the local Bay segment and, therefore, a methodology is not needed to further suballocate the loading to contributing jurisdictions or neighboring basins.

Building from the basin-jurisdiction nutrient allocations described above, the following key steps were taken:

- Assessed water clarity/SAV criteria attainment across all Bay segments containing the shallow-water bay grass designated use under the proposed basinwide nutrient cap loads and the corresponding phosphorus-based sediment loads allocated by major river basin by jurisdiction (Note: For most non-point source controls for phosphorus, there is a co-benefit of also reducing sediment)
- Identified those individual Bay segments still not attaining their applicable water clarity/SAV WQS at the allocated basinwide nutrient cap loads and the corresponding phosphorus-based sediment loads, and addressed the remaining non-attaining segments

6.4 Assessing Attainment of Proposed Amended Chesapeake Bay Water Quality Standards

This subsection describes the application of all of the processes described earlier in this section. EPA identified the draft nutrient allocations to the basin-jurisdictions in a letter of July 1, 2010, from EPA Region 3 to the jurisdictions (USEPA 2010f). Furthermore, using a separate methodology as described in Section 6.2 for allocating loads for sediment, an August 13, 2010, letter from EPA to the jurisdictions identified the draft sediment allocations (USEPA 2010g). Note that these draft allocations to the jurisdictions were derived to achieve proposed amended Chesapeake Bay WQS anticipated by the jurisdictions.

6.4.1 Establishing Nutrient Load Caps to Attain the Proposed Amended Water Quality Standards

The proposed amendments to the Bay jurisdictions' WQS are described in Section 3.3. The allocations in those letters are the allocations on which the jurisdictions based their draft Phase I WIPs. The full process for establishing these nutrient basin-jurisdiction allocations is described below:

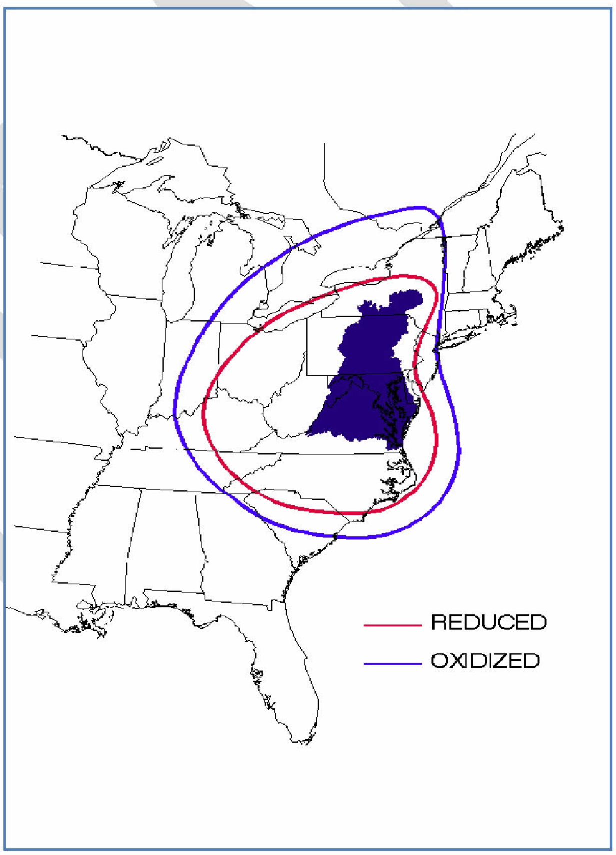
- Established the atmospheric deposition allocations on the basis of addressing the requirements of the CAA to meet existing national air quality standards
- Set the basinwide nutrient loads on the basis of attaining the applicable DO criteria in those Bay segments (middle Chesapeake Bay mainstem and the lower tidal Potomac River) whose water quality conditions are influenced by major river basins and jurisdictions throughout the Bay watershed
- Distributed the basinwide nutrient loads by major river basin and jurisdiction following the methodology developed by the partnership (see section 6.2)
- Made certain discretionary adjustments to the allocations, for example for New York and West Virginia
- Allowed for individual jurisdictions to exchange nitrogen and phosphorus loads within and between their major river basins using specific exchange ratios
- Identified those individual Bay segments still not attaining their applicable DO/chlorophyll *a* WQS at the allocated basinwide nutrient loads and addressed the remaining nonattainment segments
- Derived the final jurisdiction-basin nutrient allocations to achieve the applicable WQS for DO and chlorophyll *a* in all 92 Bay segments

Individual jurisdictions further suballocated their major river basin-jurisdiction allocated loads within their draft Phase I WIPs down to their respective Bay segment watersheds within their jurisdiction. After in-depth review of the draft Phase I WIPs and resultant proposed allocations, EPA made further adjustment to the allocations as described in Section 7.

Setting the Atmospheric Nitrogen Deposition Allocation

Atmospheric deposition of nitrogen is the major source of nitrogen to the Chesapeake Bay watershed, greater than the other sources of fertilizer, manures, or point sources. For that reason, it is necessary to allocate an allowable loading of nitrogen from air deposition in the Chesapeake Bay TMDL. The nitrogen loadings come from many jurisdictions outside the Chesapeake Bay watershed. Figure 6-8 shows the approximate delineation of the Bay airshed. Of the nitrogen air deposition loads in the Chesapeake watershed, 75 percent come from within the Bay airshed. That means that a quarter of the nitrogen loads originate beyond the airshed, and in the largest sense, the source of atmospheric loads to the Chesapeake Bay watershed are global. That is reflected in the Bay Airshed Model, which has a domain of all North America (with boundary conditions to quantify global nitrogen sources). About 50 percent of the oxidized nitrogen (NOx) atmospheric deposition loads to the Chesapeake watershed and tidal Bay come from the seven Bay watershed jurisdictions.

By including air deposition in the Bay TMDL's LAs, the Bay TMDL accounts for the emission reductions that will be achieved by seven watershed jurisdictions and other states in the larger Bay airshed. If air deposition and expected reductions in nitrogen loading to the Bay were not included in the LAs, other sources would have to reduce nitrogen discharges/runoff even further to meet the nutrient loading cap. Because CAA regulations and programs will achieve significant decreases in air deposition of nitrogen by 2020, EPA believes the TMDL inclusion of air allocations (and reductions) is based on both the best available information with a strong reasonable assurance that those reductions will occur. The TMDL being developed for the Chesapeake Bay will reflect the expected decreases in nitrogen deposition and the 2-year federal milestones will track the progress of CAA regulations and programs.



Source: Dr. Robin Dennis, USEPA/ORD/NERL/AMAD/AEIB

Figure 6-8.Principal areas of nitrogen oxide (blue line) and ammonia (red line) emissions that contribute to nitrogen deposition to the Chesapeake Bay and its watershed (dark blue fill).

In determining the allowable loading from air deposition, EPA separated the nitrogen atmospheric deposition into two discreet parcels: (1) atmospheric deposition occurring on the land and nontidal waters in the Bay watershed, which is subsequently transported to the bay; and (2) atmospheric deposition occurring directly onto the Bay tidal surface waters.

The deposition on the land becomes part of the allocated load to the jurisdictions because the atmospheric nitrogen deposited on the land becomes mixed with the nitrogen loadings from the land-based sources and, therefore, becomes indistinguishable from land-based sources. Furthermore, once the nitrogen is deposited on the land, it would be managed and controlled along with other sources of nitrogen that are present on that parcel of land. In contrast, the atmospheric nitrogen deposited directly to tidal surface waters is a direct loading with no land-based management controls and, therefore, needs to be linked directly back to the air sources and air emission controls.

EPA included an explicit basinwide nitrogen atmospheric deposition allocation in the Bay TMDL determined to be 15.7 million pounds of nitrogen atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters (Appendix L) (see Section 8.1). Activities associated with implementation of CAA regulations by EPA and the jurisdictions through 2020 will ensure achievement of this allocation and are already accounted for within the major river basin by jurisdiction nitrogen allocations. Any additional nitrogen reductions realized through more stringent air pollution controls at the jurisdictional level, beyond minimum federal requirements to meet air quality standards, may be credited to the individual jurisdictions through future revisions to the jurisdictions' WIPs, 2-year milestones, and the Chesapeake Bay TMDL tracking and accounting framework.

In determining the amount of air controls to be used as a basis for the Bay TMDL air allocation, EPA relied on current laws and regulations under the CAA. Those requirements, together with national air modeling analysis, provided the resulting allocated load to air from direct deposition to the tidal surface waters of the Bay and its tidal tributaries (Appendix L).

The air allocation scenario represents emission reductions from regulations implemented through the CAA authority to meet National Ambient Air Quality Standards for criteria pollutants in 2020. The air allocation scenario includes the following:

- The Clean Air Interstate Rule (CAIR) with second phase and the Clean Air Mercury Rule (CAMR)
- The Regional Haze Rule and guidelines for Best Available Retrofit Technology (BART)
- The On-Road Light Duty Tier 2 Rule
- The Clean Heavy Duty Truck and Bus Rule
- The Clean Air Non-Road Diesel Tier 4 Rule
- The Locomotive and Marine Diesel Rule
- The Non-road Large and Small Spark-Ignition Engines Programs
- The Hospital/Medical Waste Incinerator Regulations

The controls described above were modeled using the Community Multiscale Air Quality (CMAQ) national model, which enabled quantification of deposition direct to the Chesapeake Bay tidal waters to be determined. That approach is the basis for the previously mentioned 15.7 million pounds per year.

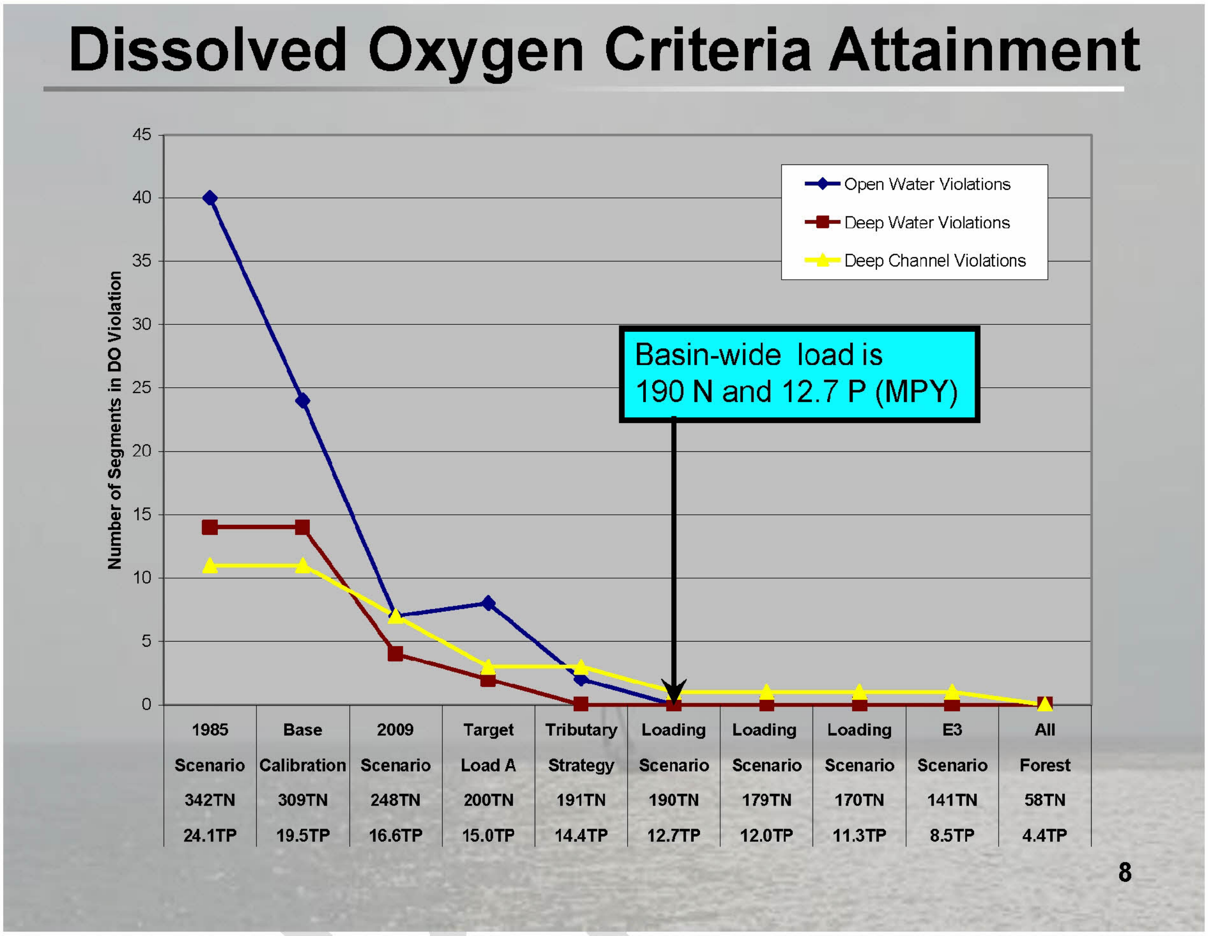
Appendix L provides a more detailed description of the process for establishing the atmospheric deposition allocations for nitrogen.

Determining the Basinwide Nutrient Target Load Based on Dissolved Oxygen

With the air allocated loads being proposed at 15.7 million pounds per year, the next step in the process was to determine the basinwide nutrient loadings that would cause the mainstem Bay and major tidal river segments—all influenced by nutrient loads from multiple jurisdictions—to achieve all the applicable DO WQS. DO WQS were used for this basinwide loading determination because the numerical chlorophyll *a* WQS apply to only the tidal James River and the District of Columbia's tidal waters of the Potomac and the Anacostia rivers and, therefore, are not affected by the other basins in the watershed. The principal Bay segments that were most important for determining the basinwide nutrient loads were the middle mainstem Bay segments CB3MH, CB4MH, and CB5MH (Maryland and Virginia) and the lower tidal Potomac River segment POTMH_MD because their water quality conditions are influenced by all river basins through the Bay watershed. Therefore, achieving attainment in these segments will necessitate nutrient reductions from all basins.

The process used for determining the load that will achieve the DO WQS in these segments was to progressively lower the nutrient loadings simulated in the Bay Water Quality Model and then assess DO WQS attainment for each loading scenario. Numerous iterations of different load scenarios were run until the appropriate nutrient loadings to achieve standards could be determined (Appendix M).

Figure 6-9 shows the numerous water quality model runs that were performed at various loading levels and the resulting water quality results. The water quality measure on the vertical axis is the number of Bay segments that were not attaining the applicable Bay DO WQS. As can be expected, as loadings are lowered throughout the Bay watershed, the number of DO WQS non-attaining segments was reduced. At the loading of 190 million pounds per year of nitrogen and 12.6 million pounds per year of phosphorus, only one Bay segment was in nonattainment for DO—part of the Chester River (discussed later in this section). Therefore, the nutrient loadings of 190 million pounds per year of nitrogen and 12.6 million pounds per year of phosphorus were selected as the basinwide loadings necessary to attain the main Bay DO standards and to distribute those loadings among the major river basins and jurisdictions in the Chesapeake Bay watershed. Note that Figure 6-9 represents the segments considered to be in nonattainment after other lines of evidence, beyond the Bay Water Quality Model, were considered.



Note: This graph expands some of the 92 TMDL segments into separate jurisdiction-segments so that the total number of Open Water, Deep Water, and Deep Channel is 98, 14, and 11 respectively

Figure 6-9. Chesapeake Bay water quality model simulated DO criteria attainment under various nutrient loading scenarios.

Allocating Nutrient Loads to Jurisdictions within the Bay Watershed

With the exception of New York and West Virginia, all the watershed jurisdictions agreed to the method described above for allocating loadings to the major river basins and jurisdictions. Using the methods described above, the relative effectiveness of each of the major river basins in the Bay watershed was determined and plotted as dots on the lines in Figures 6-10 and 6-11. To determine the basin-jurisdictions represented by each of the points on Figure 6-10 and Figure 6-11, see Table 6-2. On the vertical axis is the percent of controllable load that would correspond to the allocated load for each basin-jurisdiction. For example, 100 percent represents that all sources would have all control technologies and practices approved by the partnership installed. The horizontal axis represents the relative effectiveness of each of the basin-jurisdictions, a measure of the impact that a pound of nutrients has on the DO concentrations in the Chesapeake Bay. The wastewater (WWTP) line (red line in each figure) was first constructed based on the removal efficiencies of established treatment technologies.

The *other sources* line (blue line in both figures) was then constructed by having a difference of 20 percent of controllable load when comparing facilities/lands in the basin-jurisdiction with the highest relative effectiveness with the facilities/lands in the basin-jurisdiction with the lowest relative effectiveness. As can be seen in Figure 6-10 and Figure 6-11, facilities/lands in those basin-jurisdictions that have the highest effectiveness (or impact on the Bay) on a per pound basis must install the most controls (the basin-jurisdictions on the right of the graph). Because the dots represent the various basin-jurisdictions in the watershed, the percent of controllable load can be converted to the actual allocated load to achieve the Bay DO WQS. Finally, the allocated load for wastewater (WWTP) is added to the allocated load for other sources to determine the total allocated load for each basin-jurisdiction. It must be noted that although the graph separates wastewater and other sources, this does not necessarily require the jurisdictions to use that separate wastewater or other sources loading in their WIPs for suballocating the loads.

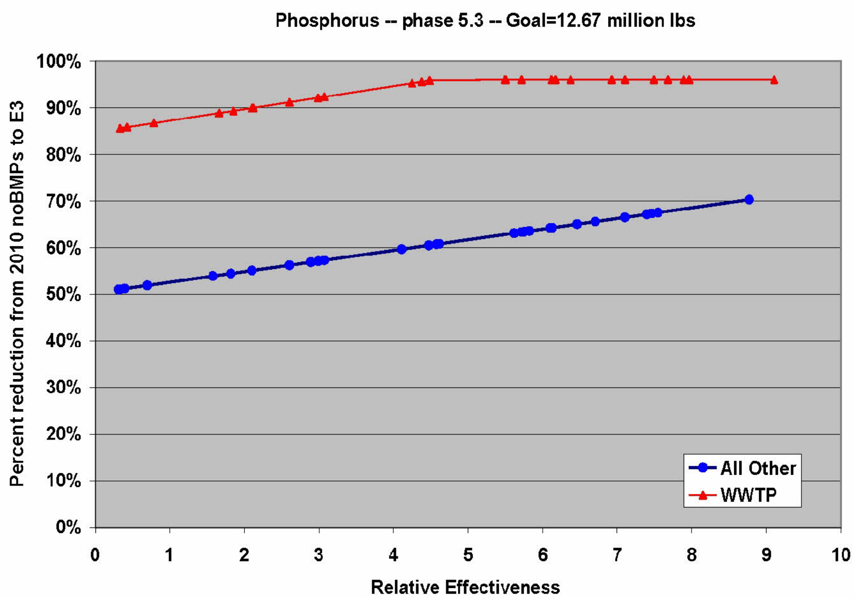


Figure 6-10. Example allocation methodology application for phosphorus.

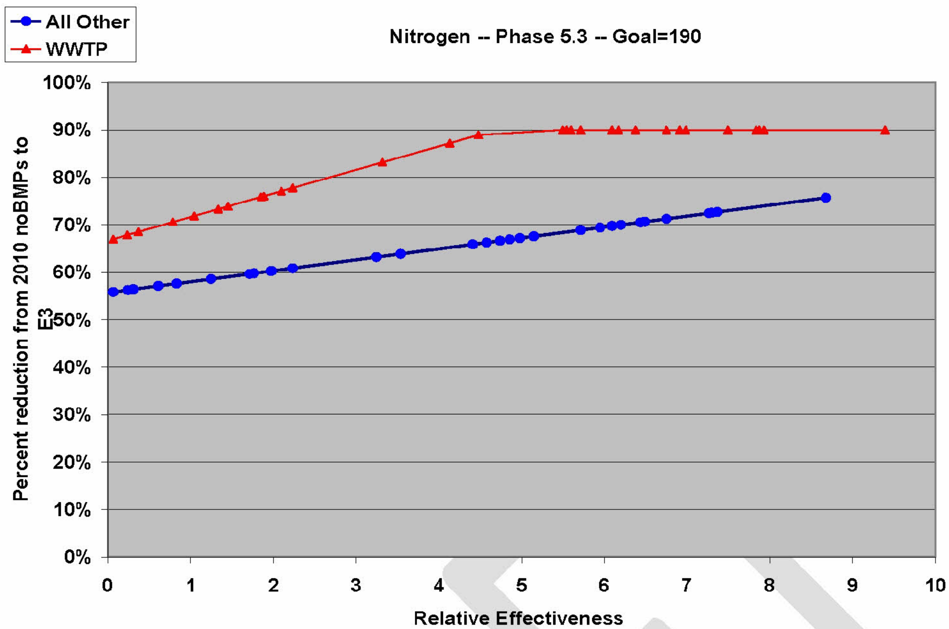


Figure 6-11. Example allocation methodology application for nitrogen.

Resolving Dissolved Oxygen and Chlorophyll a Nonattaining Bay Segments

After determining the target basinwide allocation and distributing that loading to the major basins river and jurisdictions using the methodology illustrated above, 11 designated use segments remained for which the Bay Water Quality Model was predicting nonattainment of the applicable Bay DO WQS (**Error! Reference source not found.**). Note that the nine segments out of attainment for the open-water designated use represent only about 1 percent of the total volume of open-water habitats in entire Chesapeake Bay.

Table 6-7. Chesapeake Bay designated use segments showing percent nonattainment of the applicable Bay DO WQS under the proposed basinwide nutrient target loadings (shaded column)

CBSEG	309TN, 19.5TP, 8950TSS	248TN, 16.6TP, 8110TSS	200TN, 15TP, 6390TSS	191TN 14.4TP, 6462 TSS	190TN, 13TP, 6123TSS	190TN 12.7TP, 6030TSS	179TN 12.0TP, 5510TSS	170TN 11.3TP, 5650TSS	141TN 8.5TP, 5060TSS	All Forest
	'93-'95	'93-'95	'93-'95	'93-'95	'93-'95	'93-'95	'93-'95	'93-'95	'93-'95	'93-'95
Open Water Summer Monthly										
GUNOH	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
MANMH	1%	5%	5%	5%	5%	5%	5%	5%	5%	0%
MDATF	39%	19%	18%	12%	12%	12%	11%	11%	0%	0%
MPCOH	42%	31%	25%	25%	18%	18%	5%	5%	5%	0%
PMKTF	11%	5%	5%	5%	5%	5%	5%	2%	1%	1%
POCTF	43%	32%	25%	25%	18%	18%	5%	5%	5%	0%
VPCOH	41%	28%	25%	25%	18%	18%	5%	5%	5%	0%
WBEMH	11%	15%	8%	8%	8%	8%	8%	8%	0%	0%
WICMH	11%	11%	15%	5%	5%	5%	5%	5%	5%	4%
Deep Water										
MAGMH	35%	35%	16%	16%	16%	3%	3%	1%	1%	0%
Deep Channel										
CHSMH	38%	27%	14%	14%	14%	14%	14%	9%	4%	0%

Source: Appendix M

The model also predicted nonattainment for chlorophyll *a*- all five Bay segments of the tidal James River in Virginia and the two Bay segments in the District of Columbia (tidal Potomac and Anacostia rivers) were also predicted to be in nonattainment of each jurisdictions' respective chlorophyll *a* WQS based on model runs at the basinwide nutrient loading of 190 million pounds per year nitrogen and 12.6 million pounds per year phosphorus allocated by major river by jurisdiction. This section and the supporting Appendix N explore the process by which the persistent nonattainment at reduced loading levels was resolved for each of these Bay segments.

Dissolved Oxygen Nonattaining Segments

The drivers of persistent nonattainment in these segments were examined. With the notable exception of the lower Chester River segment (CHSMH), it was generally found that nonattainment in a Bay segment resulted from two or more of the following factors:

1. Less-than-expected change in DO concentrations from the calibration to a given reduced nutrient load scenario
2. Poor agreement between model-simulated and historically observed DO concentrations for a particular location and historical period
3. Unusually or very low DO concentrations, which were very difficult to bring into attainment of the open-water DO criteria even with dramatically reduced loads

The majority of those segments are in small and relatively narrow regions of the Bay's smallest tidal tributaries. Such conditions constrain the Bay Water Quality Model's ability to effectively integrate multiple drivers of DO concentrations. As a result, the Bay Water Quality Model's ability to simulate the water quality changes in response to dramatically reduced loads was also limited. In such cases, additional lines of evidence were used to determine whether a segment could be expected to achieve the applicable WQS under the reduced nutrient loads.

Each Bay segment was evaluated to determine (1) whether violations of the DO criteria were isolated or widespread; (2) whether nearby segments also exhibited persistent or widespread hypoxia or both; and (3) whether the Bay Water Quality Model predicted sufficient improvements in DO concentrations to achieve DO WQS in nearby deeper, wider segments. Results of the evaluations, documented in detail in Appendix N, are summarized as follows.

Gunpowder River (GUNOH)

Monitored DO concentrations over the 10-year period of 1991–2000 were almost universally well above the open-water criterion of 5 mg/L. A single instance of moderate hypoxia, combined with poor model agreement and an almost complete lack of response by the Bay Water Quality Model to load reductions in the monitored location for the relevant month, resulted in persistent nonattainment across all reduced loading scenarios for the month in question. In contrast, nearby Bay segments—Bush River (BSHOH), Middle River (MIDOH), and upper Chesapeake Bay (CB2OH)—all attained their respective DO WQS when loads were reduced to the target basinwide allocation of 190 million pounds per year TN and 12.6 million pounds per year TP. Given those factors, EPA believes that Gunpowder Run can reasonably be expected to attain its DO WQS at the target loadings of 190 million pounds per year TN and 12.6 million pounds per year TP.

Manokin (MANMH), Maryland Anacostia (MDATF), West Branch Elizabeth (WBEMH), Pamunkey (PMKTF), and Wicomoco (WICMH) Rivers

Similar to the Gunpowder River segment, few violations of the open-water DO criteria occurred in these five Bay segments, and Bay Water Quality Model simulations did not match well with historically observed water quality conditions. The Bay Water Quality Model often failed to simulate hypoxia for these locations under observed loads; thus, it was also unable to estimate improved DO concentrations when nutrient loads were reduced. Nearby deeper, wider regions generally attained DO WQS at or before the target basinwide loadings. Given those factors, EPA believes these Bay segments can reasonably be expected to attain the DO WQS at the target loadings of 190 million pounds per year TN and 12.6 million pounds per year TP.

Upper and Middle Portions of the Pocomoke River (POCTF, POCOH_MD, POCOH_VA)

These three Bay segments of the narrow, Eastern Shore tidal Pocomoke River are all represented by the same water quality monitoring station and a single Bay Water Quality Model cell. The range of DO concentrations simulated by the Bay Water Quality Model did not match well with historically observed conditions in this location. The persistent nonattainment shown by the model was driven by a single violation of the WQS with the reduced load scenarios. Downstream segments (e.g., POCMH) achieved attainment at the target basinwide loading. Furthermore, it was confirmed that this river is influenced by natural tidal marshland that naturally depresses DO concentrations of the river. Maryland and EPA believe that because of the documented influence of wetlands on water chemistry in the Pocomoke River, the current open-water DO 30-day mean criterion of 5 mg/L is not appropriate. As discussed in Section 3, Maryland is proposing an alternative site-specific criterion for this segment, consistent with EPA's published guidance (USEPA 2004a). The proposed allocated loads for this river system will achieve the proposed criterion of 4.0 mg/L. Virginia is proposing to analyze the conditions of the Pocomoke River to demonstrate that the lower DO is caused by natural conditions.

Magothy River (MAGMH)

Summer hypoxic conditions were not uncommon in the Magothy River from 1991–2000, particularly when episodes of water column stratification prevented mixing of the bottom waters with more oxygenated surface waters. An episodic deep-water designated use was added to MAGMH to account for periods of water column stratification (USEPA 2010a). However, some violations of the deep-water DO 30-day mean criterion of 3.0 mg/L persisted even when nutrient loads were reduced to the target basinwide allocation. Because of the small, embayment nature of the Magothy River, the Bay Water Quality Model again struggled to simulate observed conditions in MAGMH or consistently estimate a response of sufficiently improved DO in response to load reductions. However, the deep-water region of the adjacent mainstem segment CB3MH attained its DO WQS well before the target basinwide nutrient LAs. Given the poor simulation of MAGMH conditions by the Bay Water Quality Model, the significant load reductions already required of the Magothy River basin at the target basinwide LAs, the considerable influence of the mainstem Chesapeake Bay on MAGMH water quality conditions, and the predicted attainment of CB3MH deep-water well before the target basinwide loading, EPA determined that MAGMH can reasonably be expected to attain its DO WQS at the target loadings of 190 million pounds per year TN and 12.6 million pounds per year TP.

Lower Chester River (CHSMH)

On the basis of further exploration of the modeling results for this segment and for neighboring segments, EPA concluded that the projected lower Chester River's deep-channel DO criterion nonattainment as shown in **Error! Reference source not found.** is valid. What could be observed from these Bay Water Quality Model results was that the nonattainment improves but persists, even at an E3 scenario, until an *All Forest* scenario. Also, the basinwide-based allocations for the Chester River watershed represent very stringent levels of controls. For those reasons, Maryland is proposing in its WQS regulations a variance of 14 percent for the deep-channel portion of the lower Chester River segment. EPA is proposing the primary Bay TMDL scenario to use the basinwide nutrient target load-based allocations according to the proposed

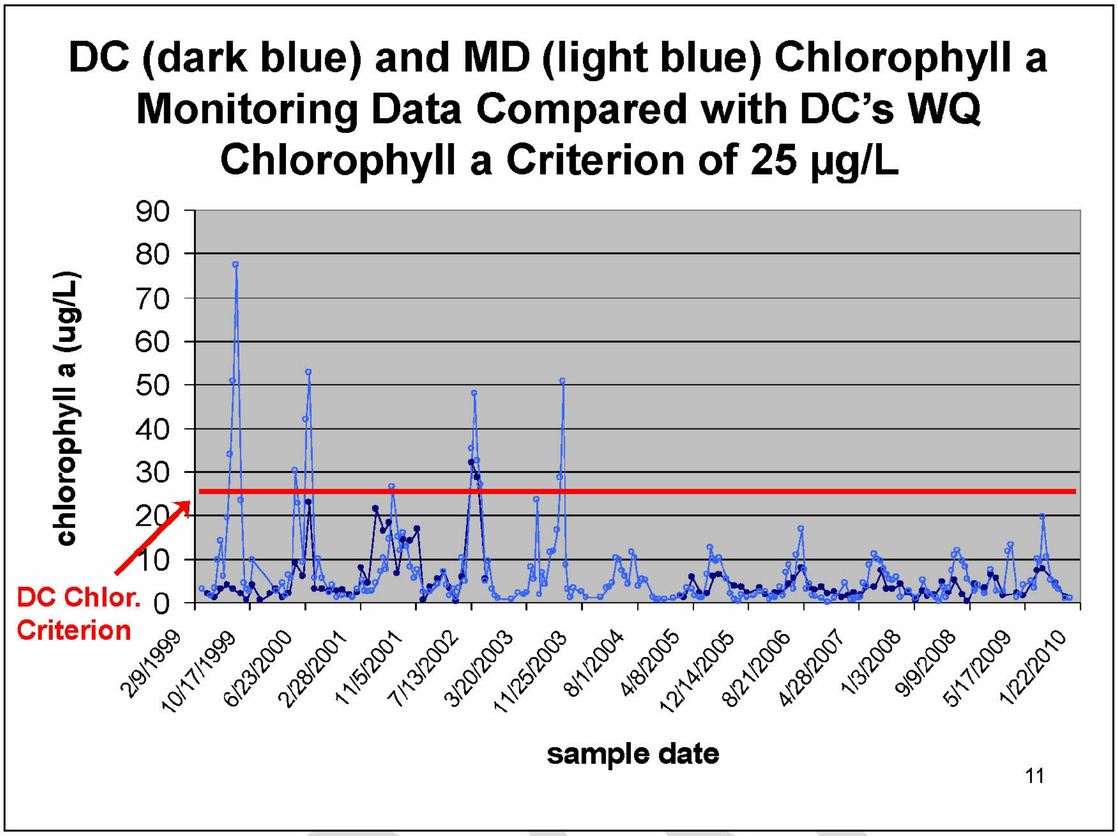
WQS modifications to the Chester River watershed to ensure WQS. EPA is also proposing another Bay TMDL scenario on the basis of current WQS (assuming the Chester River and other proposed WQS do not become effective before finalization of this TMDL).

Chlorophyll *a* Nonattaining Segments

Potomac and Anacostia Rivers in DC

The Bay Water Quality Model projected that the District of Columbia's portions of the Potomac and Anacostia river segments would be in nonattainment of the applicable numeric chlorophyll *a* WQS at the proposed basinwide nutrient target loads allocated to these two river basins. However, through diagnostic analysis of the modeled chlorophyll *a* simulations for the Potomac and Anacostia rivers in the District of Columbia, EPA determined that the Bay Water Quality Model did not reliably simulate measured chlorophyll *a* levels. Therefore, other lines of evidence (i.e., monitoring data) were weighed more heavily by EPA in the attainment determination (Appendix N). Through further investigation, EPA analyzed recent chlorophyll *a* data for the two segments. The actual monitoring data show that the Potomac River segment is attaining the District's chlorophyll *a* WQS and has been attaining that standard for at least the past 7 years (Figure 6-12). In the Anacostia River segment, a 4 percent level of nonattainment was found, again using current water quality monitoring data (Appendix N).

Because these two Bay segments will experience significant further lowering of the present nutrient levels upon achievement of the nutrient loadings under the proposed allocations scenario, EPA has concluded that both of the Bay segments will be in attainment with the chlorophyll *a* WQS under these nutrient allocations (Appendix N). Additionally, a TMDL for biochemical oxygen demand and nutrients was approved by EPA in 2008 for the *Anacostia River Basin Watershed in Montgomery and Prince Georges Counties, Maryland and the District of Columbia* (USEPA 2008). That TMDL for the Anacostia River requires significant nutrient reductions that, when implemented, will result in attainment of the chlorophyll *a* standard.



Source: http://www.chesapeakebay.net

Note: DC station PMS44 is on the Potomac River at the Woodrow Wilson Memorial Bridge (50 meters upstream of the draw span). TMD station TF2.1 is on the Potomac River at Buoy 77 off the mouth of Piscataway Creek.

Figure 6-12. Potomac River chlorophyll a monitoring data compared with the District's chlorophyll *a* water quality criteria.

James River in Virginia

In general, the Bay Water Quality Model is well-calibrated to the tidal James River and effectively simulates average seasonal conditions in the five tidal segments of this river. The Bay Water Quality Model also consistently estimates improved chlorophyll *a* conditions with increasing nutrient load reductions. At the same time, however, the Bay Water Quality Model does not simulate individual algal bloom events, which are highly variable and caused by numerous factors, some of which are still not well understood by the scientific community. The chlorophyll *a* WQS adopted in Virginia's regulation to protect the tidal James River were set at numerical limits for spring and summer seasonal averaged conditions, not for addressing individual algal bloom events lasting hours to days. Therefore, EPA's determination of nutrient loadings required to attain chlorophyll *a* WQS in the tidal James River was based on those years and Bay (James River) segments for which the Bay Water Quality Model reliably simulated the water quality monitoring-based chlorophyll *a* calibration data. That approach was used to determine the James River basin target LA of 23.5 million pounds per year TN and 2.35 million pounds per year TP.

However, at the target James River LA, nonattainment of the summer chlorophyll *a* WQS persisted in the lower tidal fresh James segment (JMSTFL) for the summer periods of 1995–

2000, and in the James River mouth segment (JMSPH) for the 1997–2000 summer periods (Appendix Q). Because these remaining nonattainments represented monitoring algal bloom conditions and the Bay Water Quality Model did not reliably simulate the calibration data, the nonattainment model results were not used to establish the James River allocations (Appendix N). Instead, the allocations were established on the basis of the remaining Bay segments, spring and summer seasons, and years where the Bay Water Quality Model simulation was reliable.

Figure 6-13 shows the number of segments and 3-year periods in nonattainment of Virginia's James River chlorophyll *a* WQS (out of the simulation period of 1991–2000) for the various load scenarios simulated, using those model results where the model is reliably simulating the calibration data (Appendix N). From the graph it can be seen that the James River does not fully attain the chlorophyll *a* WQS until a loading of 23.5 million pounds per year of nitrogen and 2.35 million pounds per year of phosphorus was achieved. For that reason, EPA determined the allocations to the James River necessary to achieve the chlorophyll *a* criteria is 23.5 million pounds per year of nitrogen and 2.35 million pounds per year of phosphorus.

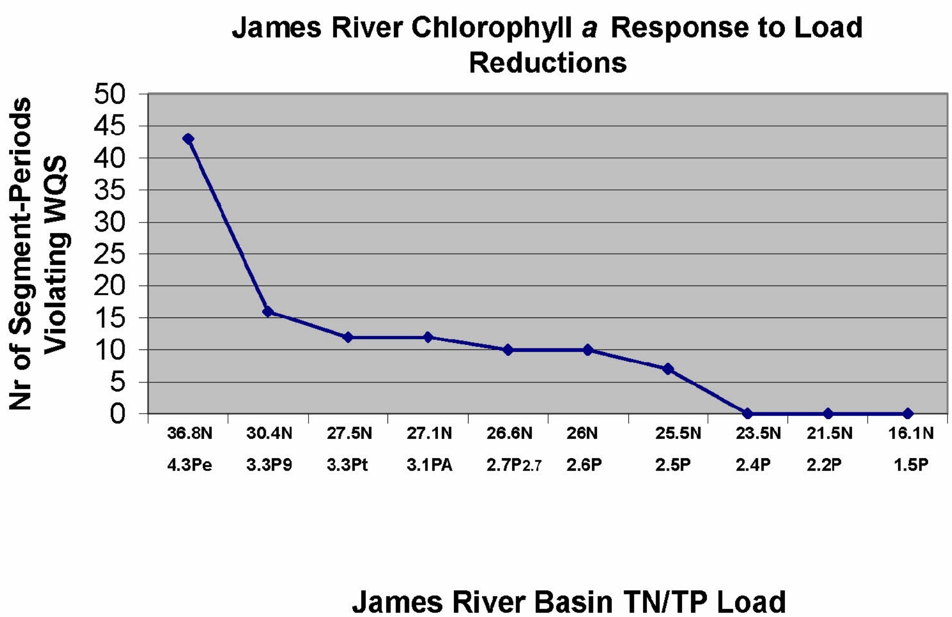
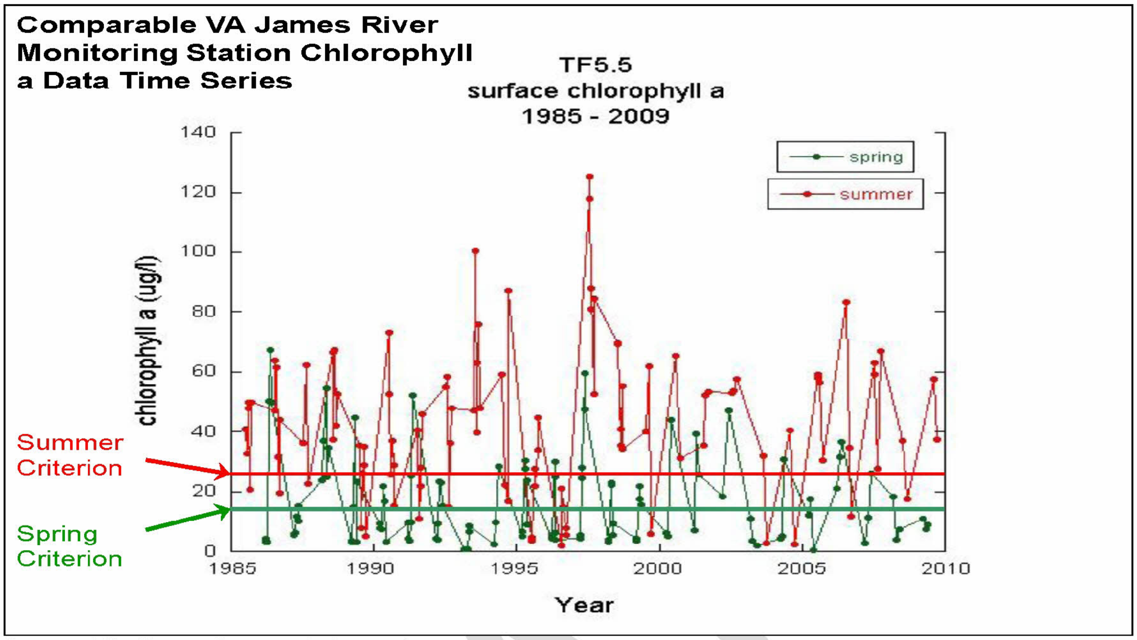


Figure 6-13. James River nonattainment of the chlorophyll a standards at various load scenarios.

Similar to the EPA analysis of attainment of the District of Columbia's chlorophyll *a* criterion using upper tidal Potomac and Anacostia River chlorophyll *a* monitoring data, EPA also assessed attainment using chlorophyll *a* monitoring data for the tidal James River. In contrast to the District's tidal Anacostia and Potomac river segments, EPA found that the past and current monitoring data for most of the tidal James River segments showed significant nonattainment of Virginia's chlorophyll *a* WQS (Appendix N). An example of the comparative analysis of the monitored data for the James as compared to Virginia's segment-season specific chlorophyll *a* criteria is shown in Figure 6-14 EPA therefore has continued to rely on the model results in assessing the appropriate allocations of nutrients.



Source: http://www.chesapeakebay.net

Figure 6-14. Tidal James River monitoring data for chlorophyll *a* at station TF5.5 (located in the upper tidal James River near Hopewell, Virginia) compared to Virginia's James River segment-season specific chlorophyll *a* criteria.

Allocation Considerations for the Headwater States (New York–West Virginia)

The methodology described above for distributing the basinwide loading was accepted by all jurisdictions except New York and West Virginia. From an additional model run, EPA determined that additional assimilative capacity was available. EPA used its discretionary authority to allocate to New York an additional 700,000 pounds per year of nitrogen (above the allocation calculated for New York using the method used to distribute the basinwide loads of 190 million pounds per year of nitrogen and 12.6 million pounds per year of phosphorus). In addition, EPA used its discretionary authority to allocate to West Virginia an additional 200,000 pounds per year of phosphorus (above the level allocated to West Virginia using the allocation methodology to distribute the basinwide load of 190 million pounds per year of nitrogen and 12.6 million pounds per year of phosphorus). EPA, through model analysis, confirmed that those loadings will achieve WQS in the Chesapeake Bay. EPA provided the additional allocations because

- Following the principles and guidelines as expressed in Section 6.3, tributary basins that contribute the most to the Bay water quality problems must do the most to resolve those problems (on a pound per pound basis). The headwater jurisdictions of New York and West Virginia contribute small portions of the overall nutrient delivered to the Bay (5 percent) and therefore are provided some relief in their allocations.
- On the basis of information provided by New York, the water quality from the streams and rivers coming from the headwaters is generally of better quality than that of downstream waters.

- The allocation methodology accommodates to some extent future growth by providing WLAs for wastewater treatment facilities at design flow rather than actual flow, thereby reserving a load for expansion of the facility.
- New York considered the methodology to be biased against Bay watershed jurisdictions that are growing relatively slowly, like New York.
- A cleaner Bay provides greater benefit (in terms of commercial and recreational benefits of a cleaner bay) to the tidal jurisdictions than to the nontidal jurisdictions such as New York and West Virginia.

Nitrogen-to-Phosphorus Exchanges

EPA permitted the jurisdictions' to propose the exchange of nitrogen and phosphorus loads within major river basins at a 1:5 ratio for reducing existing allocated phosphorus loads in exchange for increased nitrogen loads and a 15:1 ratio for reductions in existing allocated nitrogen loads I exchange for increased phosphorus loads. For example, in state allocations, for every 1 pound of phosphorus reduced, 5 pounds of nitrogen can be added and for every 15 pounds of nitrogen reduced, 1 pound of phosphorus can be added. This section documents the technical basis for those exchange rates.

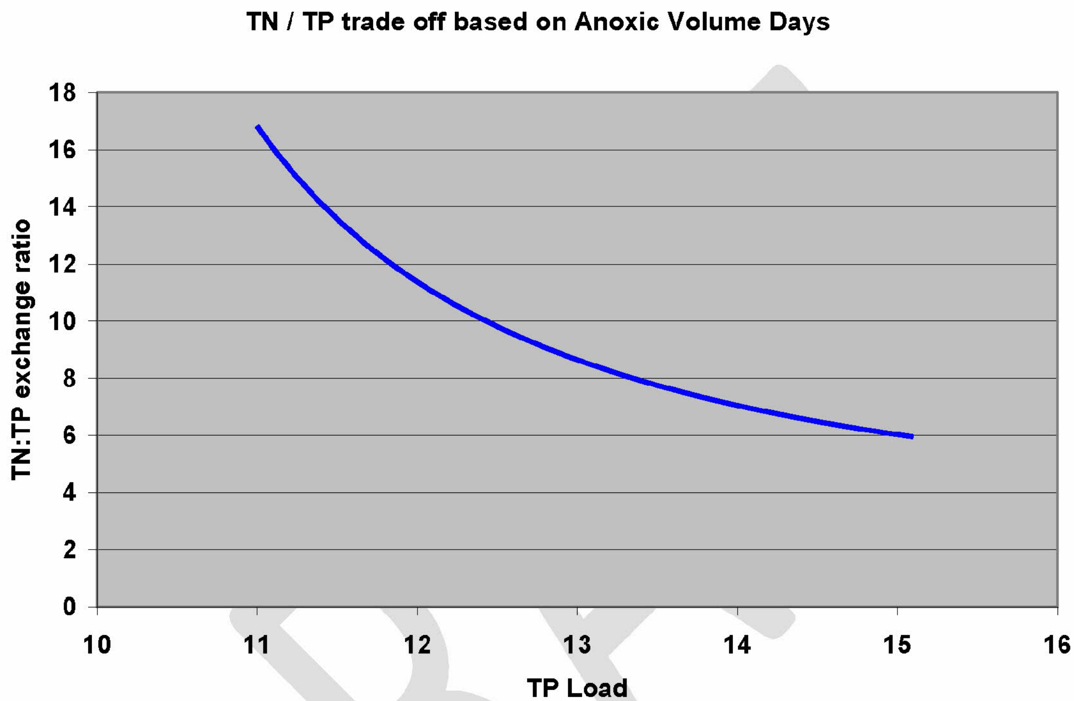
Two scientific papers published in recent years specifically address tradeoffs between nitrogen and phosphorus. The two analyses were completed with earlier versions of the Bay Watershed Model and the Bay Water Quality Model, but the results can still be meaningful if used to put bounds on the exchanges on a bay-wide scale.

Wang et al. (2006) published response surface plots for chlorophyll *a* concentrations and anoxic volume days using a matrix of nitrogen and phosphorus load reduction scenarios. The response surface plots were generated by applying equations predicting overall chlorophyll *a* concentrations and anoxic volume days as quadratic functions of the nitrogen and phosphorus fraction of 2000 loading levels. Applying the Phase 5.3 Bay Watershed Model generated values in these same equations to assess the area around the allocation levels of 187.4 million pounds total nitrogen (TN) and 12.52 million pounds total phosphorus (TP), one can use the derivatives of the original published equations to determine estimated TN:TP exchange relationships.

Figure 6-15 illustrates the TN:TP exchange ratio for different levels of TP based on the Anoxic Volume Days metric. At the allocation level of 12.52 million pounds of TP, the calculated exchange ratio is about 9:1, but the ratio has a good deal of variability. Considering that these are earlier versions of the Bay Watershed and Bay Water Quality models applied to the current reduction percentages, the local exchange ratio may vary depending on the location of the basin within the Bay. Given the degree of variability in this graph, a conservative approach is warranted. Figure 6-16 is the same analysis, except it uses chlorophyll *a* concentration in place of Anoxic Volume Days. The exchange ratios are lower, putting a greater importance on TP overall.

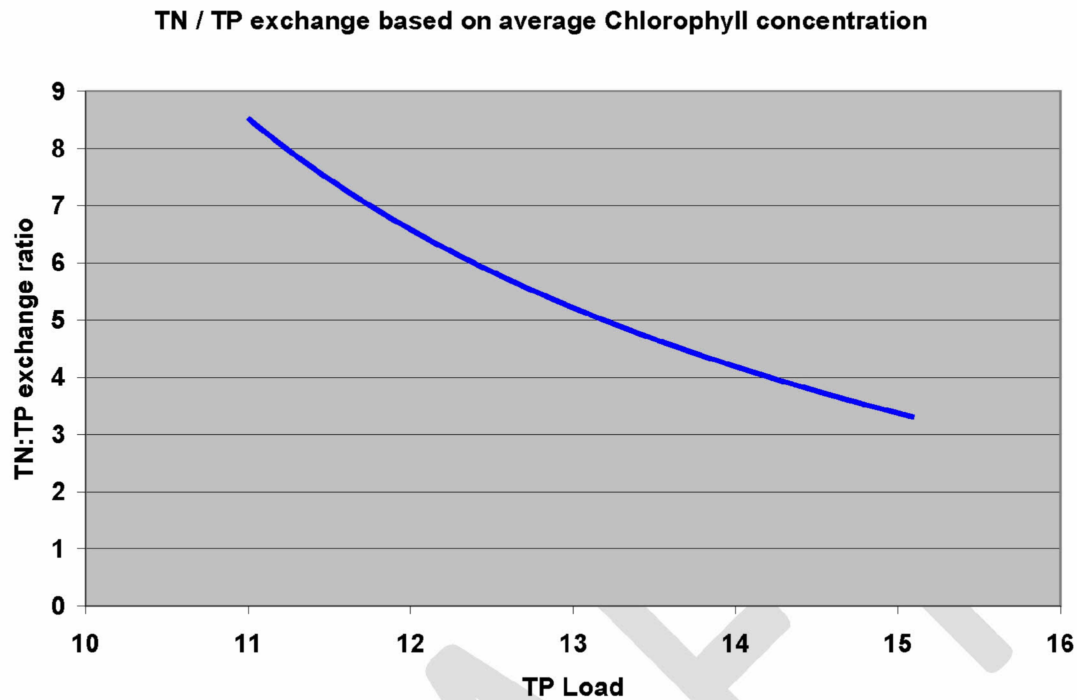
Wang and Linker (2009) documented an application of the earlier Bay models to the deep-water designated use of the upper central Chesapeake Bay segment CB4MH and determined a TN:TP exchange ratio of roughly 5:1 for that region of the mainstem Bay.

Taking both of those analyses and the two published papers into account, an asymmetrical exchange ratio of 5:1 TN:TP when allowing more nitrogen loads and lowering the phosphorus load, and a ratio of 15:1 TN:TP when allowing more phosphorus loads and lowering the nitrogen load are recommended. All applications of these TN:TP exchanges are confirmed to not affect the attainment of the jurisdictions' Bay WQS through follow-up Bay Water Quality Model scenarios.



Source: Wang et al. 2006

Figure 6-15. Total nitrogen:total phosphorus exchanges based on anoxic volume days and varying total phosphorus loads.



Source: Wang et al. 2006.

Figure 6-16. Total nitrogen (TN): total phosphorus (TP) exchanges based on chlorophyll a concentrations and varying total phosphorus loads.

Proposed Basin-Jurisdiction Nutrient Allocations

After performing all the analyses described above, EPA determined the allocations needed to attain the proposed WQS for DO and chlorophyll *a* for each basin-jurisdiction (see Section 9). The jurisdictions used the allocations to develop their draft Phase I WIPs that further suballocate the nutrient loadings to finer geographic scales and to individual sources or aggregate source sectors.

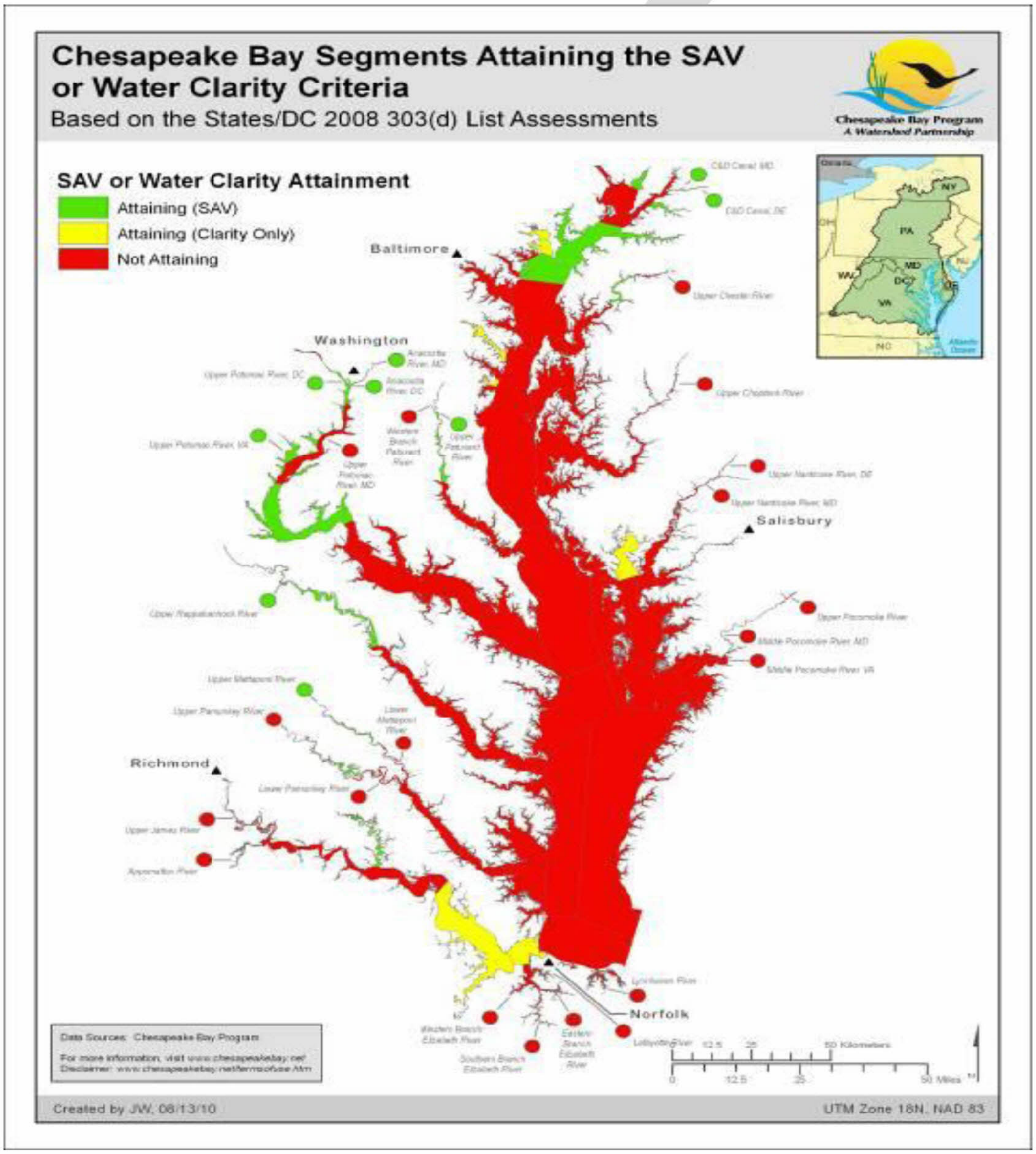
6.4.2 Determining the Sediment Load Caps to Achieve the Proposed Amended Water Quality Standards

Building from the basin-jurisdiction nutrient allocations described above, the key steps were taken:

- Assessed water clarity/SAV criteria attainment across all Bay segments containing the shallow-water bay grass designated use under the above nutrient loads and the corresponding phosphorus-based sediment loads.
- Identified those individual Bay segments still not attaining their applicable water clarity/SAV WQS at the allocated basinwide nutrient loads and the corresponding phosphorus-based sediment loads, and addressed the remaining nonattainment segments.

Of the 92 tidal Bay segments assessed by Maryland, Virginia, Delaware, and the District of Columbia, 26 achieve the respective jurisdiction's SAV/water clarity WQS on the basis of available monitoring data (Appendix P). Twenty segments have mapped SAV acreages meeting the segment-specific SAV restoration acreage in the jurisdiction's WQS (single best year of the past 3 years). Of the 12 water clarity acre assessments that were performed, an additional 6 segments were found to attain the jurisdiction's water clarity criteria based on an analysis of shallow-water monitoring data (Figure 6-17).

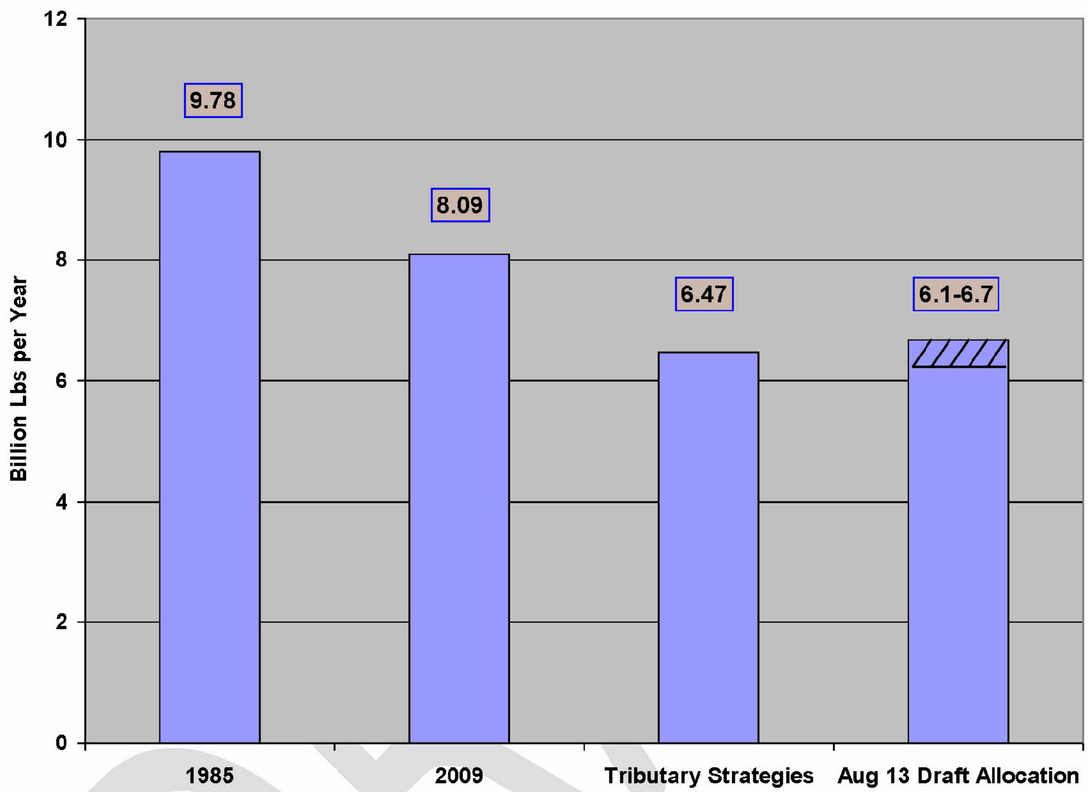
However, the Bay Water Quality Model projected widespread attainment at existing loading levels, yet the existing SAV water quality data show SAV/water clarity WQS nonattainment in 66 of 92 segments with only 46 percent of the Bay-wide restoration acreage achieved. The existing state of scientific understanding has resulted in the Bay Water Quality Model to be optimistic in its simulation of SAV acreage in the Bay under current (2009) pollutant loads.



Sources: DC DOE 2008; DE DNREC 2008; MDE 2008; VA DEQ 2008; Appendix Q.

Figure 6-17. Chesapeake Bay SAV/Water Clarity WQS attainment from monitoring data assessment.

In a TMDL, where there is uncertainty, an explicit MOS is appropriate. The sediment allocations reflect this application of an explicit MOS (see Section 6.2.3). Also by initially expressing the draft sediment allocations as a range, EPA allowed the jurisdictions some flexibility in developing their draft Phase I WIPs while assuring with confirmation model runs that all the WQS would be met.



Source: USEPA 2010g

Figure 6-18. Model simulated sediment loads by scenario compared with the draft range of sediment allocations (billions of pounds per year as total suspended sediments).

Addressing Water Clarity/SAV Nonattaining Segments

Ultimately, four segments were in nonattainment of the SAV-water clarity WQS at the nutrient and sediment reductions of the allocation scenario, which achieved all other DO, chlorophyll *a*, SAV, and water clarity WQS. Three of those segments, the Back River (BACOH), upper Chester River (CHSTF), and the middle Pocomoke River (POCOH), required nutrient and sediment load reductions at either the E3 or all forest levels to achieve the SAV-water clarity WQS (Appendix R).

The three segments were unique in that their SAV-water clarity WQS were set using a hypothetical SAV coverage back-calculated though 100 percent attainment of the water clarity criteria (see Table V-2 on page 54 in USEPA 2007a). All other Chesapeake segments had their SAV-water clarity WQS set using the maximum SAV ever observed in a record that goes back at least 40 years and in some areas back longer than 70 years (USEPA 2003c). EPA included this methodology in its 2007a WQS Addendum but is now reconsidering whether a clarity-based approach for setting the SAV goal is advisable. Maryland has proposed changing the SAV-water clarity WQS for these three Bay segments to be consistent with the approach uses in all other Chesapeake Bay segments and expects to complete the process before the end of 2010.

Appendix R provides more details of the resolution found for segments that failed to meet the SAV-water clarity WQS at nutrient and sediment loads equivalent to the allocation scenario.

Back River

SAV had not historically been observed in the Back River until 2004, when 30 acres were observed for the first time. The current SAV goal of 340 acres, based on the estimated area that is equal to all of the area of the application depth (0.5 m) divided by 2.5, is unattainable even under estimated nutrient and sediment loads of the all forest scenario. However, all the adjacent segments to Back River (BACOH), including the Middle River (MIDOH) and the upper Chesapeake Bay (CB2OH), achieved the SAV/water clarity WQS on the basis of observed SAV acres in 2009. On the basis of all these lines of evidence, the current WQS in the Back River might be overly stringent, and if the new standard proposed by Maryland (consistent with the approach for setting the SAV-water clarity WQS elsewhere in the Bay) is adopted, the Back River is estimated to fully achieve the proposed WQS under the draft allocation scenario (Appendix N). If the proposed amended WQS-based allocation scenario is implemented, the estimated reduction in sediment loads will be about 22 percent from current loads.

Upper Chester River

As in the Back River, until 2005 no SAV had been observed in the upper Chester River segment (CHSTF). In 2005 one acre of SAV was observed for the first time in more than 40 years. The SAV goal of 230 acres is based on the estimated area that is equal to the entire area of the application depth (0.5 m) divided by 2.5, and is unachievable even at the E3 level of nutrient and sediment reduction. The recently proposed WQS by Maryland is based on the maximum level of observed SAV would achieve water WQS. Sediment loads at the draft allocation scenario are estimated to be about 29 percent below estimated current sediment loads in this watershed.

Middle Pocomoke River

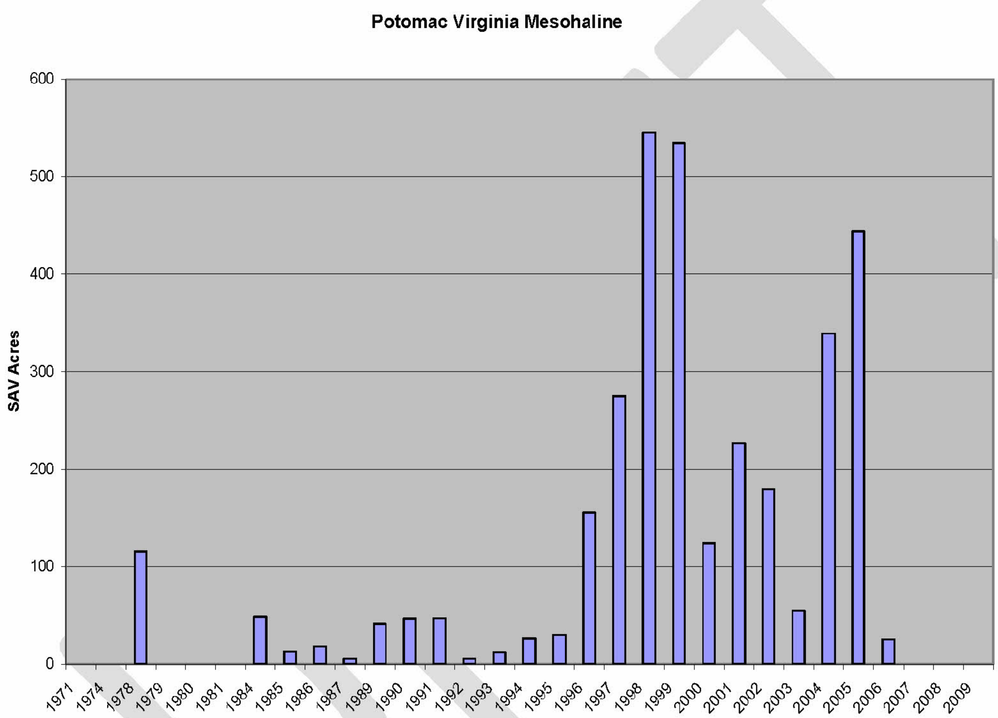
SAV had not historically been observed in the middle Pocomoke River (POCOH) (USEPA 2003c). The SAV goal of 22 acres is based on the estimated area that is less than or equal to the entire area of the application depth (0.5 m) divided by 2.5. Maryland is proposing a change in its WQS for this segment of the Pocomoke River (POCOH_MD) to reflect a SAV no-grow zone, consistent with the adjacent upper Pocomoke River segment (POCTF) consistent with EPA guidance (USEPA 2004e). The presence of no observed SAV would result in an SAV or water clarity acre goal of zero acres.

That is the case in the Virginia portion of the middle Pocomoke River (POCOH_VA), where no SAV or water clarity acre goal is in Virginia's WQS regulations. The *color* in the Pocomoke River black water system is the major cause of natural light attenuation and the lack of SAV presence in these waters.

Virginia's Lower Potomac River

Virginia's lower Potomac River segment (POTMH_VA) has an SAV restoration acreage of 4,250 acres in Virginia's WQS regulations. The draft allocation scenario has a relatively low level of 10 percent nonattainment. That level of nonattainment is persistent and was estimated to be 9 percent at E3 scenario and 6 percent at the all forest scenario nutrient and sediment load levels (Appendix J). The reason for this persistence is the lack of shallow-water habitat (less than 2 meters) in this segment to achieve the clarity criterion and thereby to support SAV growth. The POTMH_VA has a high SAV goal, yet with the described assessment methods it is estimated to largely achieve WQS the 10,625-acre water clarity criteria based mostly on water clarity alone.

The observed SAV record shows overall improvement in SAV and use of recent years. The use of the recent observed SAV area (in 2004–2005) would achieve the SAV-water clarity WQS (Figure 6-19) and sediment loads at the Allocation Scenario are 20 percent below estimated current sediment loads in this watershed (Appendix N).



Source: http://www.vims.edu/bio/sav

Figure 6-19. Observed SAV acres in Virginia's lower Potomac River segment.

6.5 Assessing Attainment of Current WQS

As mentioned above, states are proposing amendments to their WQS. This TMDL document indentifies the process and results of deriving TMDL allocations to achieve the proposed amended WQS. This subsection describes the process and results of deriving the allocations to achieve the current WQS.

6.5.1 Establishing Nutrient Basin-Jurisdiction Load Caps

The steps described above are for developing the basin-jurisdiction allocations to achieve proposed amended Chesapeake Bay WQS. Some of the same steps were used for developing basin-jurisdiction allocations to achieve the Bay jurisdictions' current Chesapeake Bay WQS.

The overall process for deriving basin-jurisdiction cap loads to achieve current WQS is described below.

Atmospheric deposition: To achieve the current water quality standards, the same air deposition allocations were used to achieve the current water quality standards as was used for proposed water quality standards.

Basinwide load: Again using the same process as described above, the model output for various loading model runs were compared to current WQS. From this analysis, WQS were not achieved until all basin-jurisdictions were at E3 levels of nitrogen and phosphorus loading. Basinwide E3 nutrient loading levels are needed to bring all 92 Bay segments into attainment with the current WQS. The basinwide loads at E3 equivalent loading levels are 141 million pounds per year of nitrogen and 8.65 million pounds per year of phosphorus.

Distribution of the Bay-wide load among the basin-jurisdictions: The methodology described above for distributing this basinwide load was not used for achieving current WQS. That is because the allocation should not drive any basin-jurisdiction beyond E3 levels unless needed to do so to achieve the Bay jurisdictions' WQS. To achieve current WQS, since E3 was needed basinwide, all basin-jurisdictions were allocated E3 level of controls. Therefore, no methodology for dividing the Bay-wide load, like that used for the proposed amended Bay WQS cap loads, was needed to derive the cap loads to achieve the current WQS.

Nonattaining segments: Even at E3 loading levels the Bay Water Quality Model predicted that there would be some Bay segments in nonattainment with the jurisdictions' current Bay DO WQS. However, on further review of the Bay Water Quality Model output with other lines of evidence, these segments were found to be in attainment at the E3 loading levels. A brief discussion of the analysis and findings for these previously nonattaining segments is provided below.

The drivers of persistent nonattainment in these segments were examined. With the notable exception of the lower Chester River segment (CHSMH), it was generally found that nonattainment in any given segment resulted from two or more of the following factors:

1. Less-than-expected change in DO concentrations from the Bay Water Quality Model calibration to a given reduced nutrient load scenario
2. Poor agreement between the Bay Water Quality Model-simulated and historically observed DO concentrations for a particular location and historical period (e.g., station ET10.1 for June 1993)
3. Unusually or very low DO concentrations, which were very difficult to bring into attainment of the open-water DO criteria even with dramatically reduced loads

The majority of these Bay segments are in small and relatively narrow regions of the Bay's tidal tributaries. Such conditions constrain the Bay Water Quality Model's ability to integrate multiple drivers of DO concentrations. As a result, the Bay Water Quality Model's ability to simulate the water quality responses to dramatically reduced loads was also limited. In such cases, additional lines of evidence were used to determine whether a given segment could be expected to achieve the applicable WQS.

Each Bay segment was evaluated to determine whether violations of the DO criteria were isolated or widespread; whether nearby segments also exhibited persistent or widespread hypoxia; and whether the Bay Water Quality Model predicted sufficient improvements in DO concentrations to achieve DO WQS in nearby deeper, wider segments. Results of these evaluations, documented in detail in Appendix R, are summarized as follows.

Gunpowder River (GUNOH)

DO concentrations over the 10-year period 1991–2000 were almost universally well above the open-water criterion of 5 mg/L. A single instance of moderate hypoxia, combined with poor model agreement and an almost complete lack of response by the Bay Water Quality Model to load reductions in the monitored location for the relevant month, resulted in persistent nonattainment across all reduced loading scenarios for the month in question. In contrast, nearby Bay segments—Bush River (BSHOH), Middle River (MIDOH), and upper Chesapeake Bay (CB2OH)—all attained their respective DO WQS when loads were reduced to the target basinwide allocation of 190 million pounds per year TN and 12.6 million pounds per year TP.

Manokin (MANMH), Maryland Anacostia (MDATF), West Branch Elizabeth (WBEMH), Pamunkey (PMKTF), and Wicomoco (WICMH) Rivers

Similar to the Gunpowder River segment, few violations of the open-water DO criteria occurred in these Bay segments and Bay Water Quality Model simulations did not match well with historically observed water quality conditions. The Bay Water Quality Model often failed to simulate hypoxia for these locations under observed loads; thus, it was also unable to estimate improved DO concentrations when nutrient loads were reduced. Nearby deeper, wider regions generally attained DO WQS at or before the target basinwide loadings.

Upper and Middle Portions of the Pocomoke River (POCTF, POCOH_MD, POCOH_VA)

These three Bay segments of the narrow, Eastern Shore tidal Pocomoke River are all represented by the same water quality monitoring station and a single Bay Water Quality Model cell. The range of DO concentrations simulated by the Bay Water Quality Model did not match well with historically observed conditions in this location. The persistent nonattainment shown here was driven by a single persistent violation of the WQS with the reduced load scenarios, and downstream segments (e.g., POCMH) achieved attainment at the target basinwide loading. Furthermore, it was confirmed that the river is influenced by natural tidal marshland that naturally depresses DO concentrations of the river. Maryland and EPA believe that because of the documented influence of wetlands on water chemistry in the Pocomoke River, the current open-water DO 30-day mean criterion of 5 mg/L is not appropriate. Maryland is proposing an alternative, site-specific criterion for this segment, consistent with EPA's published guidance (USEPA 2004a).

Magothy River (MAGMH)

Summer hypoxic conditions were not uncommon in the Magothy River 1991–2000, particularly when episodes of water column stratification prevented mixing of the bottom waters with more oxygenated surface waters. An episodic, deep-water designated use was added to MAGMH to account for periods of water column stratification (USEPA 2010a). However, some violations of the deep-water DO 30-day mean criterion of 3.0 mg/L persisted even when nutrient loads were reduced to the target basinwide allocation. Because of the small, embayment nature of the Magothy River, the Bay Water Quality Model again struggled to simulate observed conditions in MAGMH or consistently estimate a response of sufficiently improved DO in response to load reductions. However the deep-water region of the adjacent mainstem segment CB3MH attained its DO WQS well before the target basinwide nutrient LAs. Given the poor simulation of

MAGMH conditions by the Bay Water Quality Model, the dramatic load reductions already required of the Magothy River basin, the considerable influence of the mainstem Chesapeake Bay on MAGMH water quality conditions, and the predicted attainment of CB3MH Deep Water, it was determined that MAGMH can reasonably be expected to attain its DO WQS at the E3 loading levels.

Lower Chester River (CHSMH)

On the basis of further exploration of the modeling results for this segment and for neighboring segments, EPA concluded that the projected lower Chester River's deep-channel DO criterion nonattainment as shown in Table 6-7 above is valid. What could be observed from the Bay Water Quality Model results was that the nonattainment improves but persists, even at an E3 scenario, until an all forest scenario. Also, the basinwide-based allocations for the Chester River watershed represent very stringent levels of controls.

Piankatank River (PIAMH)

Under historical conditions, the level of WQS nonattainment in the Piankatank River (PIAMH) was low (< 1 percent). However, percent nonattainment actually increased in the load reduction scenarios. Further investigation revealed that in this small tributary adjacent to CB6PH, the Bay Water Quality Model did not simulate historical conditions well. The range of Bay Water Quality Model simulations was outside that of historical observations—particularly at lower depths where hypoxic or near-hypoxic conditions tended to occur—resulting in regressions that were not appropriate for use in the scenario-modification procedure. Furthermore, the adjacent mainstem segment CB6PH attained WQS (assuming the 1 percent rule) at loading levels higher than those of the E3 scenario, even with existing WQS. Given the inability of the WQM to provide estimates of the response of PIAMH to reduced loads, the attainment of CB6PH at or before E3, and the low level of WQS nonattainment under historical conditions, the EPA determines that it is reasonable to expect that PIAMH will attain current WQS E3 loading levels.

New York and West Virginia adjustment: No determination was made of additional assimilative capacity (beyond the E3 level of control), so no adjustment was made to the New York and West Virginia allocations (as was done for the allocations based on proposed WQS). Therefore, the allocations to New York and West Virginia remain at the E3 level.

6.5.2 Establishing Sediment Load Caps

As mentioned above, the effects from sediment are much more localized to the Bay segment and neighboring tidal segments receiving the sediment loading. In addition, the water clarity and SAV WQS are proposed to be amended only for the Back, Chester, and Pocomoke rivers—all in Maryland. For those reasons, the sediment proposed allocation is the same as the allocations for the proposed amended Chesapeake Bay WQS except for these segments.

For these three segments, more stringent allocations are needed in their respective surrounding watersheds. Table 6-8 shows the amount of nonattainment for each segment.

Table 6-8. Percent nonattainment of the current Chesapeake SAV-water clarity WQS for the Back, Chester and middle Pocomoke (Maryland) rivers under a range of nutrient and sediment reduction load scenarios

		*1985 Scenario	*91_00 Base Scenario	2009 Scenario	Tributary Strategy	L_190 Loading Scenario	Allocate Loading Scenario	L_179 Loading Scenario	L_170 Loading Scenario	E3_2010 P based Scenario	All Forest Scenario
BACOH	MD	69.52%	29.31%	24.94%	20.31%	26.86%	23.87%	25.06%	25.06%	23.75%	45.36%
CHSTF	MD	95.35%	95.35%	88.66%	79.74%	79.74%	79.74%	66.86%	51.36%	13.24%	0.00%
MPCOH	MD	66.83%	66.83%	7.68%	6.32%	6.32%	6.32%	3.08%	0.00%	3.08%	0.00%

Source: Appendix Q

From Table 6-8, EPA concludes that the loadings needed to attain current jurisdictions' Bay WQS for water clarity/SAV from the three Bay segments surrounding major river basin are as follows:

- Back River—While the water quality model results show that even for an all forest scenario, the SAV WQS is not achieved, an all forest loading from this basin is being proposed (Appendix N). While more analysis of this assessment is needed, it could be argued that implementing an all forest scenario would attain applicable WQS. Furthermore, while sediment impacts are local, until model results are available to confirm that an all forest loading is needed only in the Back River basin, EPA took a conservative approach to establish the TMDL for the entire Maryland Western Shore basin at the all forest loading level. Therefore, the cap allocations for the Maryland Western Shore basin to achieve the current water clarity/SAV WQS is 84 million pounds per year of sediment.
- Chester River (tidal fresh) and Pocomoke River (Oligohaline)—As with the Back River, EPA concludes from the Bay Water Quality Model results that all forest loading levels are needed to attain the current water clarity/SAV WQS for the Chester and Pocomoke rivers. However, the all forest loading cap will be applied to only the Maryland Eastern Shore basin. That is because Delaware and Virginia share very small portions of the drainage area for the Pocomoke (oligohaline) and Chester rivers. Therefore, EPA has established the Maryland Eastern Shore cap loading at an all forest loading level of 51 million pounds per year of sediment to achieve the current water clarity/SAV WQS.

6.6 Setting Draft Basin-jurisdiction Allocations

Based on all of the methods and analyses described above, EPA identified allocations for the major basins within each jurisdiction called the basin-jurisdiction allocations. These allocations are the beginning point for the development of the Bay TMDL and are provided below.

6.6.1 Basin-jurisdiction Allocations to Achieve the Proposed WQS

Throughout 2009 up until the summer of 2010, EPA and its watershed jurisdictional partners worked together to develop the basinwide and then major river basin/jurisdiction target loads. Based on these collaborative efforts, EPA shared an initial set of major river basin/jurisdiction nutrient target loads on November 3, 2009 based on decisions at the October 23, 2009 PSC meeting (USEPA 2009b). Then following a 2-day PSC meeting on April 29-30, 2010, EPA shared an updated Bay TMDL schedule and further outlined a long term commitment to an adaptive management approach to the Bay TMDL in a letter to the partners (USEPA 2010e).

One set of basin-jurisdiction allocations was based on attaining the proposed amendments to the state water quality standards. On July 1, 2010, EPA shared the draft nutrient allocations (USEPA 2010f) and the draft sediment allocations on August 13, 2010 (USEPA 2010g). These are the allocations that states used to develop their WIPs and EPA used to backstop the WIPs. These allocations are calculated as delivered loads (the loading that actually reaches tidal waters) and as annual loads. These loads are provided below in Table 6-9 and 6-10.

Table 6-9. Chesapeake Bay watershed nutrient and sediment draft allocations by major river basin by jurisdiction to achieve the proposed Chesapeake Bay WQS.

Basin	Jurisdiction	Nitrogen draft allocations (million lbs/year)	Phosphorus draft allocations (million lbs/year)	Sediment draft allocations (million lbs/year)
Susquehanna	NY	8.23	0.52	293-322
	PA	71.74	2.31	1,660-1,826
	MD	1.08	0.05	60-66
	Total	81.06	2.88	2,013-2,214
Eastern Shore	DE	2.95	0.26	58-64
	MD	9.71	1.09	166-182
	PA	0.28	0.01	21-23
	VA	1.21	0.16	11-12
	Total	14.15	1.53	256-281
Western Shore	MD	9.74	0.46	155-170
	PA	0.02	0.001	0.37-0.41
	Total	9.76	0.46	155-171
Patuxent	MD	2.85	0.21	82-90
	Total	2.85	0.21	82-90
Potomac	PA	4.72	0.42	221-243
	MD	15.70	0.90	654-719
	DC	2.32	0.12	10-11
	VA	17.46	1.47	810-891
	WV	4.67	0.74	226-248
	Total	44.88	3.66	1,920-2,113
Rappahannock	VA	5.84	0.90	681-750
	Total	5.84	0.90	681-750
York	VA	5.41	0.54	107-118
	Total	5.41	0.54	107-118
James	VA	23.48	2.34	837-920
	WV	0.02	0.01	15-17
	Total	23.50	2.35	852-937
Total Basin/Jurisdiction Draft Allocation		187.44	12.52	6,066-6,673
Atmospheric Deposition Draft Allocation[a]		15.70	--	
Total Basinwide Draft Allocation		203.14	12.52	6,066-6,673

a. Cap on atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters to be achieved by federal air regulations through 2020.

Table 6-10. Chesapeake Bay watershed nutrient and sediment draft allocations by jurisdiction by major river basin to achieve the proposed Chesapeake Bay WQS.

Jurisdiction	Basin	Nitrogen draft allocations (million lbs/year)	Phosphorus draft allocations (million lbs/year)	Sediment draft allocations (million lbs/year)
Pennsylvania	Susquehanna	71.74	2.31	1,660-1,826
	Potomac	4.72	0.42	221-243
	Eastern Shore	0.28	0.01	21-23
	Western Shore	0.02	0.001	0.37-0.41
	PA Total	76.77	2.74	1,903-2,093
Maryland	Susquehanna	1.08	0.05	60-66
	Eastern Shore	9.71	1.09	166-182
	Western Shore	9.74	0.46	155-170
	Patuxent	2.85	0.21	82-90
	Potomac	15.70	0.90	654-719
	MD Total	39.09	2.72	1,116-1,228
Virginia	Eastern Shore	1.21	0.16	11-12
	Potomac	17.46	1.47	810-891
	Rappahannock	5.84	0.90	681-750
	York	5.41	0.54	107-118
	James	23.48	2.34	837-920
	VA Total	53.40	5.41	2,446-2,691
District of Columbia	Potomac	2.32	0.12	10-11
	DC Total	2.32	0.12	10-11
New York	Susquehanna	8.23	0.52	293-322
	NY Total	8.23	0.52	293-322
Delaware	Eastern Shore	2.95	0.26	58-64
	DE Total	2.95	0.26	58-64
West Virginia	Potomac	4.67	0.74	226-248
	James	0.02	0.01	15-17
	WV Total	4.68	0.75	241-265
Total Basin/Jurisdiction Draft Allocation		187.44	12.52	6,066-6,673
Atmospheric Deposition Draft Allocation[a]		15.70	--	
Total Basinwide Draft Allocation		203.14	12.52	6,066-6,673

a. Cap on atmospheric deposition loads direct to Chesapeake Bay and tidal tributary surface waters to be achieved by federal air regulations through 2020.

6.6.2 Basin-jurisdiction Allocations to Achieve the Current WQS

In addition to the basin-state allocations for the attainment of proposed water quality standards, EPA also develop basin-jurisdiction allocations to attain existing water quality standards. These allocations were not provided to states for the development of their WIPs. But these allocations are important in the event that the state water quality standards are not amended in time for the establishment of the final TMDL by December 31, 2010. These allocations are also based on delivered load and annual load and are provided in Table 6-11 below.

In order to achieve the current water quality standards that are extant in the Chesapeake Bay today, the estimated nutrient loads must be lowered to the watershed loadings that would require an E3 level of effort described above. The allocated nutrient loads include atmospheric deposition loads equal to that in the proposed standard allocations of 15.7 mpy of nitrogen.

For the current SAV-clarity water quality standard, achievement is estimated to be achieved by the current WIP levels of TSS loads, expressed as sediment loads, except for two basins on the Maryland Eastern Shore and one on the Maryland Western Shore. The Eastern Shore basins are the Chester Tidal Fresh and the Maryland Pocomoke Oligohaline. Both of these basins require All Forest Scenario loads to achieve the SAV-clarity water quality standard. Because of the nonattainment in the Chester and the Pocomoke, the entire Maryland Eastern Shore is set at an All Forest load level for sediment only. The Back River basin of the Western Shore also requires an All Forest Scenario level of sediment reduction and so the All Forest condition is set for the entire Maryland Western Shore as well.

For all other jurisdiction-basins in Table 6-11, the following decision rules were applied using the State Watershed Implementation Plans (WIPS):

1) If the final approved WIP came in below the sediment range (from the August 13, 2010 sediment allocation letter) the sediment allocation is set to the low end of the sediment range.
2) If the final approved WIP came in within the high and low ends of the sediment range, then the sediment allocation is set at the WIP load.
3) If the WIP came in above the high end of the range then the sediment allocation is set at the high end of the sediment range.

The combined nutrient and sediment loads in Table 6-11 are estimated to fully achieve all current and existing water quality standards.

Table 6-11. Chesapeake Bay Allocations for Existing WQS by Jurisdiction

Jurisdiction/Basin	Nitrogen Allocation (million pounds/year)	Phosphorus Allocation (million pounds/year)	Sediment Allocation (million pounds (TSS)/year)
PENNSYLVANIA			
Susquehanna	56.89	1.76	1,758.2
Potomac	3.50	0.33	233.9
Eastern Shore	0.20	0.01	21.1
Western Shore	0.01	0.00	0.4
PA Total	60.59	2.10	2013.6
MARYLAND			
Susquehanna	0.87	0.04	62.9
Eastern Shore	7.18	0.83	51.1
Western Shore	5.99	0.25	81.8
Patuxent	2.03	0.13	90.1
Potomac	11.42	0.63	682.3
MD Total	27.49	1.88	968.3
Virginia			
Eastern Shore	0.79	0.12	10.9
Potomac	13.31	0.98	810.1
Rappahannock	4.39	0.60	688.5
York	3.83	0.35	107.1
James	16.45	1.55	852.8
VA Total	38.78	3.60	2,469.4
District of Columbia			
Potomac	1.47	0.05	11.2
DC Total	1.47	0.05	11.2
New York			
Susquehanna	6.39	0.43	293.0
NY Total	6.39	0.43	293.0
Delaware			
Eastern Shore	2.22	0.19	57.8
DE Total	2.22	0.19	57.8
West Virginia			
Potomac	3.61	0.37	248.1
James	0.02	0.01	16.6
WV Total	3.63	0.38	264.8
Basin/Jurisdiction Allocation	**140.57**	**8.63**	**6,078.0**
Atmospheric Deposition	15.7	-	-
Total Allocation	**156.27**	**8.63**	**6,078.0**

Attainment of the District of Columbia pH Water Quality Standard

Currently, the upper Potomac River Estuary from Key Bridge to Hains Point and the Washington Ship Cannel are on the District of Columbia 303(d) list of impaired waters. The cause of these impairment is high pH. The pH impairment may result from excess primary productivity or algal growth, which might, in turn, result from excess nutrient inputs. A simulation of the Potomac River was developed that relates pH to nutrient loading, primary production, and other factors. A key underlying assumption in this Potomac modeling framework, called the Potomac River Eutrophication Model (PEM), is that calcium carbonate equilibria and solid phase calcium carbonate (calcite) formation and precipitation are the primary buffers affecting pH in the tidal freshwater Potomac River. This assumption formed the basis for an earlier analysis (HydroQual 1988) that attempted to explain the development of a large algal bloom in the tidal freshwater Potomac in 1983.

This bloom was dominated by the blue-green alga, *Microcystis aaeruginosa.* In attempting to understand the factors contributing to a bloom of this magnitude (peak chlorophyll concentrations of 150 to 200 ug/L), the inter-relationship between pH and release of phosphorus from the bottom sediments was investigated by Seitzinger (1986). Seitzinger's data showed a clear relationship between increased pH and increased release of dissolved inorganic phosphorus (DIP) from Potomac River sediment cores. Using information from Seitzinger's data, the Potomac River Eutrophication Model was modified to include calcium carbonate equilibria and phosphorus release from bottom sediments as a function of overlying water column pH. In addition, two new algal classes were added to the three algal classes already in the Water Quality and Sediment Transport Model (WQSTM), which is the basis of the PEM.

Since the PEM is a stand-alone model, boundary conditions from the WQSTM from the final Allocations need to be provided for the mouth of the Potomac for the PEM. Work is proceeding to develop these boundary conditions in order to confirm that the allocation to achieve the proposed amendments to the DO and chlorophyll water quality standards will also achieve the pH water quality standard in DC waters. Confirmation is in progress, but based on current information, EPA expects that current allocations will be sufficient to achieve the District's pH water quality standard.